DISCOVERY

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Hunting the Basking Shark

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The Progress of Science

Chloromycetin, a Promising Antibiotic

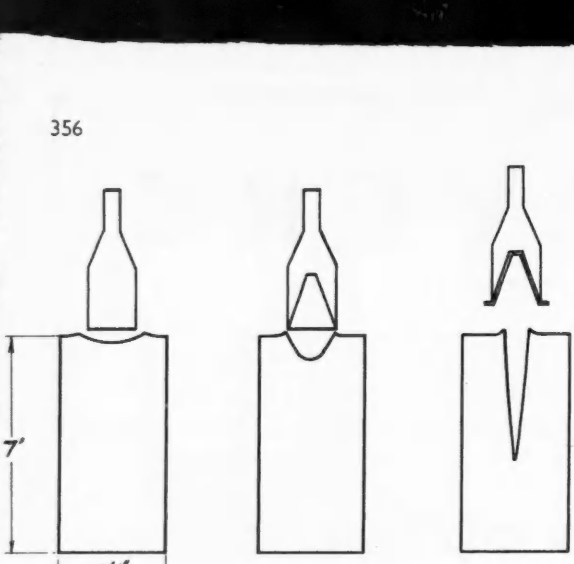
As soon as the remarkable properties of penicillin were fully realised an intensive search was made to see whether micro-organisms other than *Penicillium notatum* produced substances antagonistic towards disease bacteria and suitable for use in chemotherapy. At first the search was sporadic but as more and more workers entered this extraordinarily promising field it became possible to carry out the investigations systematically. In laboratories throughout the world, and especially in Britain and America, thousands of different micro-organisms have been grown, under a variety of conditions, and the products of their growth have been tested for anti-bacterial activity.

In general the results obtained have been disappointing and it has become increasingly clear that luck as well as genius played an important part in the development of penicillin. It was largely a matter of chance that Florey and Chain chose *P. notatum*, from many known possibilities, for what promised to be no more than an academic study of the antagonism of one micro-organism for others. Equally it was a matter of chance that this particular example, the first to be subjected to exhaustive examination by modern methods, proved a medical winner. During the last few years many similar examples of antagonism have been very closely investigated—several of which might originally have been chosen by Florey and Chain—and in more than a score of cases the specific substance responsible has been isolated and tested for chemotherapeutic value. None, however, is in the same class as penicillin and few appear to have any important medical possibilities. Only streptomycin and aerosporin have so far justified much optimism, and the full value even of these remains to be assessed. Hopes raised by such substances as patulin, notatin, gliotoxin, and helvolic acid have been disappointed with monotonous regularity. If research workers did not constantly have penicillin before them as an example of what may be achieved, it is certain that interest in micro-organisms as a source of new chemotherapeutic agents would have flagged long ago.

To the very short list of antibiotics which show real promise can now be added one other—chloromycetin. In clinical trials already carried out, and still proceeding, this has shown remarkable curative effect against typhus, a virus disease against which penicillin, sulphonamide (M & B) drugs, mercurial compounds, and all other known substances are quite powerless. Typhus is a louse-borne disease and therefore a consequence of poverty and overcrowding. Although it is fortunately now almost unknown in Britain it is still common in Europe, especially as a result of disordered conditions during and following the war. In Asia, too, epidemics are all too frequent. The mortality of the disease is generally not very great, though it may become so during epidemics, but if one considers the world as a whole deaths total tens of thousands every year. In addition, the disease leaves behind it a long trail of human misery and weakness. The finding of a cure for typhus is therefore a medical problem of the first importance.

Chloromycetin, which has recently been obtained in the pure crystalline state, is produced by a species of *Streptomyces*—the same family of micro-organisms as that which produces streptomycin—first isolated from a sample of soil from a field near Caracas in Venezuela. Since then it has been found to be produced also by a *Streptomyces* isolated from a compost-heap in Illinois. These two sources incidentally illustrate how widespread is the present search for micro-organisms capable of producing new chemotherapeutic drugs.

The new drug appears to fulfil almost ideally the two fundamental requirements of a chemotherapeutic agent, namely that it shall be deadly to the disease microbes which have to be destroyed and at the same time harmless to the cells of the human body. Tests with human volunteers have shown that prolonged dosing with 1 gram of chloromycetin per day causes no detectable ill-effects. It has too the great advantage that it can be taken by mouth and there is no need for injection. After it has been swallowed the drug appears in the blood within thirty minutes, reaching a maximum after about two hours. After eight hours, however, it has disappeared from the blood altogether, so that frequent dosing is necessary. In treating typhus the drug is generally given every two hours until a definite improvement in the patient is seen, and thereafter



1 SOLID CHARGE

2 HOLLOW CHARGE Munroe Effect

3 LINED HOLLOW CHARGE

FIGS. 1, 2, 3.—The effects of solid, hollow and lined hollow charges on identical steel cylinders. The latter have been cut in half to show the depth of penetration. The weight of explosive in Figs. 2 and 3 was only 4 oz. and the thickness of the mild steel liner in Fig. 3 was 25 thousandths of an inch.

less frequently for a total of fourteen days. The total daily dose now being used is about 6 grams. Chloromycetin is much more stable than penicillin. For example, it can be heated for 5 hours at 100° C. without being destroyed.

Chloromycetin had its first trials against typhus in Mexico, where a few adults were treated with spectacular success. Their temperatures fell and their condition improved rapidly, though the typical typhus rash did not disappear any quicker than usual.

Present trials, much more extensive, are being made in Malaya by Dr. J. E. Smadell, of the U.S. Army Medical Department in collaboration with two local doctors from Kuala Lumpur, Drs. Lewthwaite and Savoor. So far 25 patients have been treated. Twelve patients have been nursed under the same conditions, but without receiving the drug, to serve as controls. Of the 25 patients treated, none died, none had complications, and the average duration of fever was 7½ days. On the average all signs of fever disappeared 31 hours after chloromycetin treatment began. Of the 12 controls, one died, one suffered from serious complications, and the average duration of fever was 18 days. This difference is very striking. An important point is that half the cases treated were not in fully equipped hospitals, but in ordinary sick rooms attached to estates.

The mode of action of chloromycetin will certainly repay study, for typhus is caused not by visible bacteria—like many infectious diseases—but by a virus not visible by ordinary means. Penicillin, sulphonamides and other drugs which attack bacteria are very largely inactive against viruses. Besides attacking the typhus virus chloromycetin attacks the virus of psittacosis (parrot fever) and also a variety of harmful bacteria. It is assayed by its action on *Shigella paradysenteriae*, just as penicillin is assayed against *Staphylococcus aureus*. The tubercle bacillus also is moderately sensitive to chloromycetin, but so far its possibilities in the treatment of tuberculosis have not been investigated.

Explosives with Lined Cavities

LATE in 1944 it was announced (*see* DISCOVERY, December 1944) that "hollow charges" had been used in various new weapons and in military demolition work. It was explained that these were applications of the "Munroe effect", known since 1792, in which the force of an explosive is concentrated in a particular direction by shaping the charge into a hollow cone or wedge and applying it with the apex pointing away from the surface to be penetrated.

It has recently been revealed that an enormous advance in the effectiveness of these charges was obtained by lining the cavity with thin sheet metal. Some idea of the magnitude of the effect can be gained from Figs. 1, 2, 3. As a result of this discovery weapons capable of penetrating the armour plating of a tank without the aid of very high striking velocities were produced, amongst which were the American 'Bazooka' and the British P.I.A.T. Similar weapons were developed at about the same time by all the major combatants. The Germans had a hand-placed anti-tank bomb which adhered to the tank by means of strong permanent magnets until its time fuse exploded, and the Japanese used a suicide version in which the charge, carried on a bamboo lance, was thrust against the tank by an infantryman, with sufficient force to explode the detonator.

Many different shapes and lining materials were examined in developing these weapons, but none showed conspicuous advantages over the others, and on occasion highly effective charges were improvised by moulding plastic explosive over the outside of car headlamp reflectors.

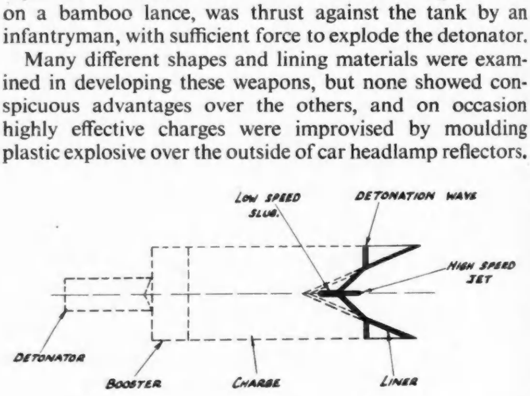


FIG. 4.

The mechanism of the effect is briefly as follows. After detonation an explosion wave travels down the charge. When this wave reaches the apex of the cone enormous pressures are developed which cause the lining to collapse towards the central axis of the cone. The inner part of the lining forms a jet of liquid metal which is squeezed out of the collapsing apex and is projected forwards with a velocity which may be as high as 30,000 feet per second, i.e. about ten times as great as the *muzzle* velocity of a rifle bullet. The outer part of the cone forms a slug of deformed metal which, although heavier than the jet, travels at less than one-tenth of its speed, and is of no importance in the subsequent effects. Fig. 4 indicates the state of affairs when the explosion wave has passed about half-way down the

cone. The jet is in process of formation and has not yet attained its maximum velocity. To obtain the maximum penetration the lined charges are exploded a short distance away from the target surface in order that the jet may be fully formed and accelerated. Unlined charges produce their greatest effect when exploded in contact with the target surface. The high-speed jet forces its way through armour plate in the same way that a jet of water penetrates a mud bank. At the point of impact the jet spreads outwards so that the size of the hole which it produces may be several times larger than the diameter of the jet itself. The pressures produced so greatly exceed the ultimate strength of the steel that its strength under normal circumstances is unimportant. In fact armour plate has little advantage over mild steel in resisting penetration by these jets. At these pressures, estimated as of the order of a quarter of a million atmospheres, or 4 million lb./sq. in. all metals flow like liquids.

The peaceful industrial application of such charges is limited by the high cost of the special explosives needed. However, several interesting proposals have been made. It has been suggested, for example, that charges fired into the walls of an oil well would increase the rate of seepage of oil through the surrounding rock. It is claimed that the use of long, wedge-shaped, hollow charges for cutting steel plates in underwater salvage operations is less dangerous than the use of oxy-acetylene cutters. Should cheaper explosives become available, there is no doubt that the ease of control which is characteristic of lined charges will prove of considerable value. In the meanwhile, various suggestions have been made for using these charges in research investigations. By varying the kind of explosive and the shape of cavity it should be possible to produce a well-graded series of dynamic pressures which will permit the study of the mechanical properties of materials at pressures which cannot be attained by any other means. The remarkable success of the theoretical investigation of the lined hollow charge in predicting the effects on various targets show that much can be done in this direction. Another interesting suggestion is that charges should be exploded in the upper atmosphere, for instance at the highest point in the flight of a V-2 rocket. The jets of metal expelled by the charges have velocities comparable with those of the slower meteors, and they should be observable from the ground. Controlled experiments with 'artificial meteors' should therefore be possible.

What a Scientist sees in Beer

WHEN we picked up the issue of *Chemistry and Industry* for May 29, 1948 our eyes alighted on an article by H. J. Bunker under the alluring title, 'Some Scientific Aspects of Beer'. What really caught our eye was the prominently displayed table on the first page headed, *Factors contributing to instability and haze formation*! On closer examination, however, it turned out that the instability and haze referred to was not the effects produced in the highest of the higher organisms by copious absorption of beer. The instability proved to be instability of the beer itself, its tendency to lose 'good condition, brilliance and correct flavour'. And the 'haze' of the provoking heading is the turbidity that one may see on looking through a glass of beer at the glaring lights of the city bar or the flickering lamps of the country inn before putting the beverage to the final test of drinking it. Among those factors which contribute to instability and haze formation, we find the presence of air and agitation—beer, like all precious things, must be kept closely sealed and treated with gentle care. Again, the presence of protein substances in the beer is a potent cause of haze formation; yet, says Mr. Bunker, "their complete elimination is not desired by the brewer because this is accompanied by loss of head retention and palatefulness". Given the truth of the last fact, which we have no reason to doubt, objections to the complete elimination of proteins will come not only from the brewer, but also from the consumer.

Having been caught out by the heading about instability and haze formation, we thought twice when we found the word *head-retention* in another sub-heading and realised it must refer to the 'beaded bubbles winking at the brim'. The connoisseur likes to see a good head on his beer, and according to Mr. Bunker "he is right, for a good foam on beer usually goes with body and flavour". It is on this subject of head-retention that we find our only opportunity of criticising Mr. Bunker for a vital sin of omission. In fact, he lists three stages in the collapse of the head: "first, a draining of the liquid from between the bubble walls; second, the uniting of small bubbles into larger ones; and third, the bursting of the bubble walls". But he has forgotten here that the foam is often removed in a much more direct manner by the use of a well-directed blast of air controlled by a member of that respected community, the froth-blowers.

It would be unfair if we left the reader with the impression that Mr. Bunker's paper is a mere subject for light-headed buffoonery. It is, of course, an excellent survey of the applications of science to brewing, written by one well qualified for the task. (Mr. Bunker is director of research to Barclay Perkins; before that he did microbiological research at the Chemical Research Laboratory.) Those who have a serious interest in the manifold ways in which science affects everyday life will do well to consult it, and even those who cannot follow in full the technicalities of "the α, β and γ portions of the globulin", or the action of proteolytic enzymes in inhibiting haze formation, will still discover much of interest. How many of us knew, for example, that at least 1250 different strains of brewers' yeast contribute in different breweries to the creation of our much-loved beer? But Mr. Bunker will forgive us, we know, for using his paper as an excuse to enliven the seriousness of these pages. Indeed, he himself has added many humorous touches to his exposition—as when he tells us that soaps, fats and oils hasten the collapse of foam, and adds "that it is not merely on hygienic grounds that the publican dislikes the presence of lipstick and the remains of fish and chips on his glasses".

The Dead Hand on Discovery

C. D. DARLINGTON, D.Sc., F.R.S.

I.—THE FINGERS OF LEARNING

Introduction

To the scientist his own work seems to consist in correctly observing and measuring what he sees and in truly describing it. By these means he hopes to arrive at conclusions without the interference of those fallacies and superstitions which abound in the great world outside. He also hopes, and believes, that these conclusions will serve to increase man's understanding and control of nature, including himself.

To the man outside, scientific discovery looks very different. It is a challenge and a threat. It challenges the respect due to parents, to institutions and to governments. It threatens the authority of scripture, the sanctity of marriage and the sovereignty of nations. It disturbs practices sanctified by generations of tradition, equally in the farmyard, in the school and in the council chamber. It uproots belief. It destroys property. It endangers life.

No wonder the terrified or enraged public reviles its practitioners as "morons in the moral sense", "unthinking automatons", "memorising a lot of scientific formulae" and striving to grind down mankind under a "technological juggernaut".

There is evidently a confusion of thought somewhere. But if we are willing to study the evidence, we can clear our minds of it. And, in doing so, we can partly remedy the dangerous conflict in our old society which arises from it.

At bottom the conflict is not between the scientist and the layman. It is not even between any particular material interests or between any particular classes. It is between the rival powers of tradition, belief and security—represented by all the established organs of society—on the one hand; and innovation, doubt and discovery, on the other. It is between those who have large fixed interests of the mind and those who have not. It is a conflict in which the same man may be on opposite sides at different times or for different purposes. It is a conflict which has existed since man chipped his first flints and lit his first fire. But today it is sharper than ever before. For the world, owing to the increasing rate of scientific discovery, is changing more quickly than ever before.

The problems that this conflict raises are broad and deep. They affect every aspect of our life and every class of society. Their study was given a name by the French savant, Charles Nicolle, nearly twenty years ago. He called it the Biology of Invention. And it is high time we made a science of it.

Academies

Let me begin at the beginning; that is with the discoverers and with the teachers. They are closely bound up together. Every teacher has to teach what was once discovered; and every discoverer has to be taught a little by some teacher. Moreover the relationship has been fortified by the institution of universities for the purpose of jointly undertaking discovery and teaching. Yet in fact, all new knowledge destroys old knowledge. Between the two activities of communicating the *old* truth and discovering the *new*, there is therefore an opposition, an opposition which is no less profound for being profoundly concealed.

When we learn that the Holy Inquisition (which interests itself in the propagation of true knowledge) objected to the teaching of the revolution of the earth by Galileo and made him recant, we are accustomed to say that this is merely an example of the well-known opposition of religion to science. But when we learn that, a little later, the Sorbonne (which also interests itself in the propagation of true knowledge) petitioned Louis XIV to prohibit the teaching of Harvey's discovery of the circulation of the blood, we see that there is something more in it than that. It is not merely a question of religion. It is rather that the stability of belief of all kinds is necessary to all men: it is necessary for their mental peace and comfort. All established thought is sacred and is opposed to scientific discovery, opposed as violently as are any of its conventional or artificial forms which we call religion.

Of course, belief becomes more necessary and more sacred as one gets older. New ideas are attractive to the young. We say that they are impressionable. But as soon as knowledge and experience combine to give ripe judgment, a feeling of repugnance for new notions develops. The apartments of the mind are fully furnished, and there is no longer room to change about; indeed if anyone suggests that there is any empty space, it is apt to be denied. For the purpose of teaching is to cover up what ignorance it cannot remedy. The picture has to be complete. Yet the region of ignorance is the very foundation of discovery. Those who know everything pat (whether it is, according to the country, Cruden's Concordance or the letters of Lenin) may win most of the academic prizes and may make their way into high administrative office. But they never make discoveries. And they do not much like other people to do so.

Now it is necessary for those who teach to believe what they teach. And it is also in the interests of their

pupils to believe it. The successful young men may be supposed to have agreed with their examiners. But looking at the results in the great perspective of history we are bound to admit that the examiners were often wrong, and most often wrong when great issues were arising. It is not an accident that Gregor Mendel was twice, on examination, refused his teacher's certificate. Nor that the subjects he failed in were botany and zoology, the ones which still resist the implications of his discoveries. It is therefore important to see that the first-class honours man is not given (what some would give him) a monopoly of scientific research.

It is for these reasons that every great discovery has been neglected or obstructed by the great universities, academies and experts of the time.

In the seventeenth century the Royal Society of London was young and enterprising in every field. But when we come to the nineteenth century, the age of progress beyond all others, the Royal Society is now an old and venerable body and we find the dead hand of the past lying heavy on it. We find it indeed, with unerring discrimination, rejecting the papers of its most daring contributors, Dalton, Waterston and Joule.

Many people imagine that these sad mistakes are historical curiosities, pleasant anecdotes. They are indeed nothing of the kind. They illustrate the habitual reaction of the academic mind to the work of genius. Today the reaction is as strong as ever. It is only a few years ago that a young man offered to the Royal Society a paper showing the revolutionary consequences of applying new mathematical treatments to biological problems. The two referees were of one mind. They rejected it; one because it contained biology, the other because it contained mathematics. The young man then offered it to the Royal Society of Edinburgh, whose resistance to discovery is known to be weaker. The Scotsmen offered to publish it. But they made the prudent proviso that owing to the great expense of printing mathematical formulæ the cost must be borne by the young man. They demanded £70. His friends collected the money and the paper thus, in the end, saw the light of day. It proved to be one of the epoch-making works of the century. But suppose the money had not been found. The rejection would then have meant suppression—as it was intended to.

One author whose paper had been rejected by the Royal Society of London was recently able to get it published by introducing a statement, prescribed by the editor, that his ideas had been put forward thirty years earlier (in 1909) by a Fellow of the Society. He believed this statement to be untrue. But he was naturally happy to secure the great boon of publication at the price of so small a perjury.

Sheltered by anonymity, referees can write with great freedom. One paper was recently rejected by a referee on the ground that too much had already been published on this subject. As a matter of fact nothing had been published in this country on this subject for fifteen years. During that time all such papers had been rejected—presumably by the same referee since it was (or had been) *his* subject.

This is a cold war perhaps. But it never stops. Great academies, while eagerly garnering for their transactions the twigs and trimmings of science, throw away or bury in their archives the heavy timber of discovery. Yet today simple souls can be found enthusiastically urging that the whole publication of scientific discovery should be put under the unified and absolute authority, or rather under the dead hand, of these same learned censors!

The logical conclusion from the principle that established institutions resist innovation and discovery is reached, as we might expect, by our logical friends the French. They have a profound respect for the institutions created by the dead hands of Louis XIV and the great Napoleon. For a long time there has been no exception to the rule that the publication of a notable discovery by a candidate for admission to the French Academy (which was founded to promote Discovery), is a fatal obstacle to his election.

Universities

When we come to a teaching organisation like a university we find that it presents far greater obstacles to innovation than a mere academy. Its teaching has to be arranged in departments. It demands the services of a carefully distributed staff with established salaries secured by established endowments. It requires elaborate buildings, equipment and books. It needs regular curricula, courses of lectures and examinations. All these arrangements are incommoded by introducing new knowledge—and, what is worse, by abandoning old, obsolete, or even discordant knowledge.

There are three steps by which new knowledge is resisted in our universities. First, the subject is kept out of the curriculum as being debatable, premature, abstruse or superfluous: too difficult, the professors *say*, for the undergraduates; too difficult, the undergraduates *know*, for the professors. Secondly, when included in the curriculum, it can be left out of the examinations. And, thirdly, anyone specialising in a new subject can be kept out of a university chair. In countries with deeply entrenched universities certain new subjects can in this way be stifled for several generations.

In our country for a long time biochemistry was the obvious example. Today genetics, cytology and statistics take its place. The fundamental developments, having had to come from outside the universities, are only now beginning to get themselves

taught: forty years' obstruction is being painfully overcome. That is why boys going up to our great universities from school often find they know more about the newest developments of science than their eminent professors.

Take one example. The theory of sampling is the most important development of scientific method in this century. Its foundations were laid in this country by R. A. Fisher twenty years ago. It is taught in secondary schools in our own dominions. It is expounded in Agricultural Colleges in the United States. And it is used in the practical administration of other countries such as India. But it is unknown to most professors of science in English universities. What indeed is twenty years in their slowly changing life?

Ours being an old country, these principles have worked to maintain in our universities an ancient structure and ancient rules corresponding to their ancient endowments so piously administered. The autonomy (or freedom, as it is called) of our older universities means their continued subjection to the dead hand of that great planner King Henry VIII. Antiquity, indeed, has become an end in itself, and we find our newer universities eager and proud to imitate the mistakes of the old ones. They are happy to lag one or two generations in some fields, and one or two centuries in others, behind the obvious needs of the times.

Now scientific research arises out of the teaching in the universities. If it is trivial research it arises in loyal discipline. If it is fundamental it arises by outrageous rebellion. But that it arises from what has been taught, none can gainsay. And since what is taught has been planned—largely by the generations of the dead—it follows that our research is always proportioned to an outmoded plan. This is what, for some reason, is usually described as freedom of research.

The freedom for research to develop from what has been taught has never been in danger anywhere. Let the teaching be planned according to living needs, and the research will plan itself in accordance with those needs. That sounds quite easy until we recall that the freedom to teach what has *not* been taught before has never existed anywhere. It has always had to be fought for, in every place and in every age. Professors are free to inquire. But men who inquire about new things are not free to become professors.

It is failure in understanding these principles—which stare us in the face as soon as they are pointed out—that is fogging the minds of those who dispute about Freedom versus Planning in research.

Barriers and Departments

The greatest obstacles in the struggle to teach new things are the departments of knowledge as they at present exist.

It used to be said truly enough that the specialist was a man who knew more and more about less and less. But the great age of this kind of specialist, whether it is in science or in the humanities, is gone. Those departments which were necessary in order to train him were always obstacles to discovery and have now even become obstacles to education. When we hear a man introduce his views by the qualification "speaking as an historian" or "speaking as an anthropologist" or "speaking as a chemist" we know, as a rule, that he is not competent to speak at all. For these disciplines have lost their absolute powers of governing their own territories.

In the past the mathematician need know nothing of statistics. The geologist need know nothing of the soil. The pathologist need know nothing of heredity or variation. The geographer could be content with the surface of things. Today such specialists find that they can no more than scratch where their predecessors dug. But against the new teaching demanded by this new situation, our universities present an iron front.

The first powerful blows which might have broken down the barriers between the compartments of human knowledge were made by the work of Darwin. But Darwin's teaching falls in no compartment. It cannot therefore be taught, and it has in fact never seriously penetrated into our universities. Nearly 100 years after the publication of his great book, *The Origin of Species*, it is still possible to take degrees in Botany, Zoology or Medicine in any British university without any understanding of the work of Darwin.

How different has been the fate of Linnaeus! The great Swedish naturalist, 100 years before Darwin, divided all nature into compartments. It was a most necessary work in the eighteenth century; but, alas! only too well suited to the organisation of universities. And in the twentieth century the dead hand of Linnaeus still lies heavy on the museums and botanic gardens and learned societies of the world, and on the mind of the oppressed student (who has to learn it all). Everywhere the work of Linnaeus resists the impact of modern science and the touch of living nature.

In the history of universities the chief barriers go back to the middle ages and beyond. But new ones are continually arising; some of them from causes that have nothing to do with the resistance to discovery. Take the University of London for example: it represents today in its jungle of colleges nothing but the survival of certain vested interests established by the religious, the economic, and the social squabbles of the nineteenth century. There is one college for the Church of England, one for Jews and atheists, a few strictly for the production of scientists and medical men, one for the working class, and two or three for those girls whose parents do not want them to meet boys. This college organisation fragments each possible department into a dozen scraps. In doing so it

destroys all hope there might be of developing a respectable university in London—one capable of comparing, for example, with the old University of Berlin.

This university, whose light (or shadow) falls over most of England, has the largest number of professors of any in the country. One might suppose that it would be prepared to deal with all the most important subjects. Yet it is in this university that vital questions have for years been omitted from the examination papers because there is no Professor or Reader or Lecturer competent to mark the answers. This means that there is no one in authority in the vast conglomeration of self-governing units who is interested in the intellectual or practical service rendered to the nation by the university as a whole: departmentalism is the highest form of life it knows, and it is difficult to say whether the Theology or the Biology is more out of date.

And outside the university no one worries either. Is there a waste of money? Well, perhaps. But, after all, money spent on education can't be wasted, can it?

History of Science

All the barriers which cut up knowledge obstruct discovery. But there is one barrier which needs to be broken down before all others. It is that which separates science from the humanities. It has to be broken down if men are to be taught how the processes work which are actually changing us, processes which in the last 200 years have largely destroyed the old civilisations of the world and brought us where we are.

Yet in our universities science is an afterthought, a practical afterthought, like the bathroom in an old house, but none the less an afterthought. Today it remains outside the plan of a general education. It must be brought into it. And the way to do so is to teach the history of science to all those who aspire to a general education.

The history of science, equally ancient and contemporary history, would aim at showing us the continually changing methods of assessing evidence, of measuring consistency, or (shall we say) of ascertaining the truth. It would explain both the difficulties and the dangers of discovery. It would try to tell us how to estimate in any field of activity the prospects of stability and change, of belief and doubt; it would indicate how much we know and how much we don't. It would also attempt to develop the Biology of Discovery.

And finally, it would put our own people and our own nation into its true position in the history of mankind: not in terms of the romantic and flattering national fairy tales which pass for history in our schools, but in terms of the co-operative international effort by which men have reached their present mastery over nature, and may conceivably reach some mastery over themselves.

Such a history of science would soon be found indispensable for those who are going to devote their lives to scientific discovery. But it would be no less indispensable for those who are bound to be concerned with its application and administration, men who in the past have so often been ignorant of everything concerned with science except the means of keeping it down.

The Dead Hand

The reform of the universities cannot relieve our present crisis. But it can prepare us for later ones. For the universities, which draw their authority from the remote past, pass it on to the remote future. They have indeed a monopoly in the future—a right to pass on the government of the dead to the generations of the unborn,

In our country, schools and museums, industries and government departments are alike founded on ancient enterprise, and are alike therefore governed by the hand of the dead. The traditions deeply entrenched in the independence of the universities therefore seem perfectly appropriate. But taken altogether, the brake they put on discovery and its application is overpowering. In other countries, colleges and universities have been created which do not copy the model handed down by the dead, but are adapted to some extent to the needs of the living, to providing the education that is wanted today; where knowledge may be regarded in its unity, where science is taught to the humanists and the humanities to the scientists; where facts and ideas are treated less as a basis of belief and repetition than as a training in inquiry; where the purpose is to discover and encourage the difference between individuals rather than to suppress them; where, in a word, the future is held to have equal weight with the past.

It is because the humane education of this kind is lacking in our universities that such a pitiful minority, such a forlorn hope, of the men chiefly responsible for our government—some 50 to 100 out of 5000—are conversant with the method and meaning of science, the remainder fearing and frustrating it. It is for this reason in turn that we have lagged behind Germany and the United States, and even Switzerland and Sweden, in our scientific, and even more in our technical, education. And that in consequence our industries now stand in such a precarious position: far behind those of our rivals, and with no possibility of recovering their lost ground save from the most urgent and drastic and fearless reform. And finally it is for this reason that the bulk of our efforts in fundamental research are misdirected in their course or delayed in

their application 10, 20 or 30 years, or even lost altogether.

But here another aspect of our affairs comes in—the political and administrative control of science. This is a department of its own.

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(Dr. Darlington's article will be concluded in our next issue.)

NEW LIGHT ON TOXINS

THE action of toxins has been till recently very much of a mystery. The extreme powerfulness of their effects is well known. One milligram of diphtheria toxin, for example, would kill about 10 tons of guinea pigs—a fact whose grimness is emphasised today by the danger that even more powerful toxins might perhaps be used as weapons of war. But to the two great problems—*What causes the bacteria to produce toxins?* and *How do the toxins exert their harmful effects?*—there was till last year hardly a clue.

Toxins are proteins. Several, like that of diphtheria, have been obtained fairly pure, and chemical analysis shows that they do not differ markedly from other proteins such as that of white of egg; for example, their composition in terms of amino-acids turns out to be similar. Therefore, one cannot explain their toxic effects in any simple terms of chemical poisoning. It must be related to some way in which the protein molecule as a whole exerts some specific biological effects—for example, by inhibiting the action of an enzyme.

That was about as much as could be guessed, when A. M. Pappenheimer of New York hit on a significant clue. He had been used to growing his diphtheria bacilli in hard glass vessels. In these conditions both the growth of the bacilli and the yield of toxin were poor. On one occasion he ran out of hard glass vessels and he used a batch of old ones made of soft glass. The yield of toxin was greatly increased. Following this up, Pappenheimer found that the increased yield could be obtained in the hard glass vessels by adding powdered soft glass. And eventually, it was discovered that the effect was due to trace quantities of iron which the soft glass yielded up to the water and the bacilli absorbed.

Further investigation showed that as the amount of iron made available to the bacilli is increased, at first both the rate of growth of the bacilli and the yield of toxin increased together. Eventually, when the iron is present in a concentration of 1 part to about 10 million parts of medium, the growth rate reaches a maximum. If the concentration of iron is further increased, the growth rate of the bacteria remains steady, but the yield of toxin *decreases*.

The diphtheria toxin is excreted by the bacteria in company with a substance belonging to a class known to chemists as the *porphyrins*. Porphyrins are complex compounds of carbon, hydrogen, and nitrogen, which play very important roles in the vital processes of both plants and animals. Their molecules are cage-like and can enclose atoms of metals such as iron and magnesium. Chlorophyll, for example, the green pigment of plants which plays an essential role in the process of photosynthesis, is a magnesium-containing porphyrin. Haemoglobin, the red pigment of blood, whose chief function is to carry oxygen from the lungs to the rest of the body, consists essentially of an iron-containing porphyrin (called *haem*) attached to a protein of the kind known as *globins*. Many important enzymes consist of protein molecules with a few molecules of haem tacked on to them.

As already explained, the yield of toxin begins to decrease if the concentration of iron rises above a certain point. Exact measurements show that for every four atoms of iron added above this limit one molecule of toxin fails to appear. At the same time four molecules of porphyrin fail to appear. This indicates that the bacterial cell excretes one molecule of toxin for every four molecules of porphyrin. As the excretion of both toxin and porphyrin decreases when the amount of iron available is increased, it must be supposed that the excess iron becomes locked up inside the bacterial cell in the form of haem, the iron-containing porphyrin. The increased retention of haem inside the cell seems to be controlled by an enzyme called *cytochrome b*, which plays an essential part in the respiration of living cells.

Putting all these facts together, Pappenheimer has suggested the following theory. The diphtheria bacillus as part of its normal life process synthesises cytochrome b, and as a preliminary step it must manufacture both the protein part of the enzyme and the porphyrin. If, then, it has a sufficient supply of iron, the iron and the porphyrin go to form haem and the haem is joined to the protein to produce the cytochrome b enzyme. But if there is a shortage of iron, the bacillus cannot finish the job. It is left with the protein part and the porphyrin, which, for lack of iron, it cannot turn into the required enzyme. Since the protein part and the porphyrin are biologically useless alone, they are then excreted. And the protein part, according to the theory, is the diphtheria toxin.

In other words the diphtheria toxin is the protein part of the enzyme cytochrome b as it occurs in animals, or at least is very similar to it. And cytochrome b is vital to the life of all animals. On that basis Pappenheimer suggests the following theory as to how the toxin kills. The cells of an animal must have some sort of automatic adjusting mechanism whose function is to detect any deficiency of the vital enzyme cytochrome b, and put in train the chemical processes that would rectify the deficiency; or correspondingly stop these processes when there is sufficient enzyme present. But the toxin which is excreted by the diphtheria bacillus and finds its way into the cell of an infected animal resembles cytochrome b so closely that the adjusting mechanism in the cell responds to it just as if it were cytochrome b. Thus a plentiful supply of diphtheria toxin is mistaken by the cell for a plentiful supply of cytochrome b. Production of the latter is stopped, and the animal suffers, and possibly dies, from a lack of it.

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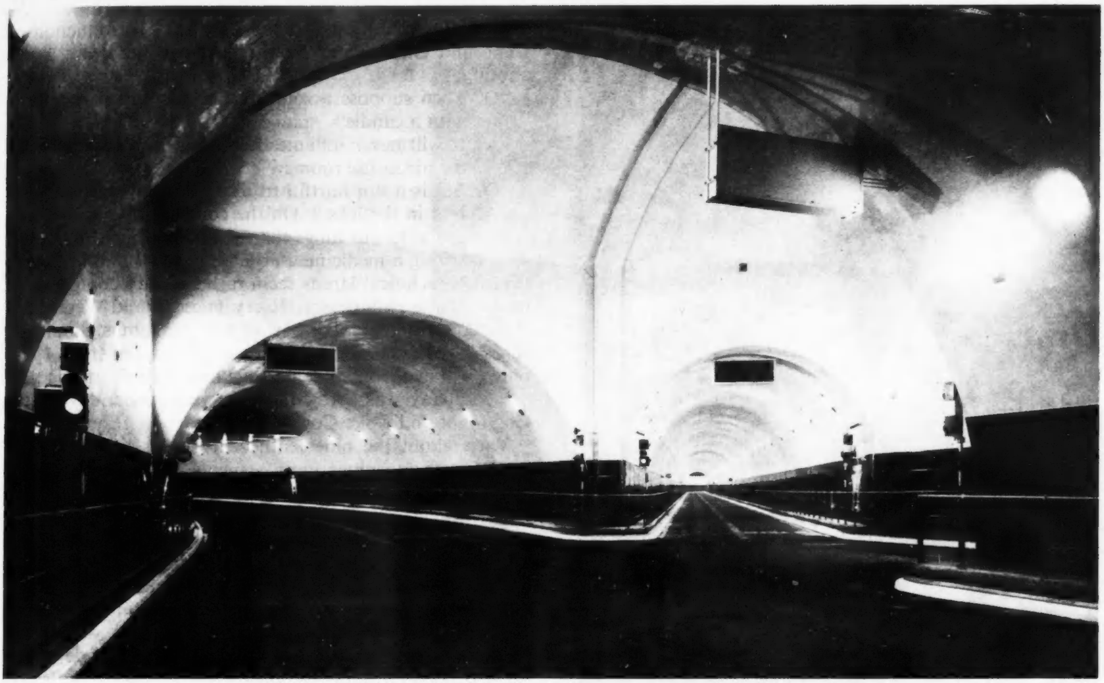

Light in the Streets

L. T. MINCHIN, B.Sc., M. Inst. Gas E.

THE provision of lighting for streets may not seem, at first glance, to be a field in which scientific effort has been very sustained or effective. In very few thoroughfares is the lighting by night comparable with the lighting by day: and at the present moment, when fuel economy cuts are in force and shortages have to be contended with, a great many of our streets are badly lit by almost any standards. The street lighting engineer, however, from the very nature of his task, labours under great handicaps even in normal times: and perhaps that is one of the reasons why the job has such a fascination. The first of these natural handicaps is the enormous discrepancy between the limited amount of light available to the engineer and the vast quantities poured so liberally on us during the day by the sun. On a clear day, in sunlight, the earth receives, even in these latitudes, ten thousand lumens* per square foot of its surface: on cloudy days the figure is still of the order of one thousand lumens per square foot. Compare this with the artificial lighting of streets, in which an average illumination of one lumen per square foot would be quite exceptionally good for a busy main road—our side-streets have, as a rule, to manage with a tenth of that amount or less. Under these conditions the eye behaves quite differently; colour contrasts are largely lost and an object which happens to have the same darkness as its background can become invisible at quite a short distance from the observer.

The second handicap is even more serious; the sun shines down from a height of 93 million miles and between it and us there is even a translucent screen—the atmosphere—which so diffuses the rays that every corner and crevice is illuminated. On occasion—as, for instance, at a hump-back bridge—this screen also provides an excellent background. How can the poor lighting engineer hope to compete with such a system, when he must perforce put his lamps up on poles sufficiently low to be reached by a tower-ladder and sufficiently far apart to make the installation reasonably economical? His lamps glare out as brilliant spots from a pitch-black background formed by the night sky. His light has to be paid for, so he cannot usually afford to lavish it on the territory on either side of the road as the sun does. As a result, the visibility on even a well-lighted road may become very poor at one spot where, because of a bend or a T-junction, bushes or an open space constitute the background. Probably the ideal way to light a road would be to roof it over completely with opal glass illuminated from above; or else to build an opaque white ceiling and walls and illuminate it by indirect fittings. The effect would then be similar to that obtained in the Mersey tunnel (Fig. 1) illustrated above. Every point on the white surface would act as a light source, and, given sufficient light-power, results as good as daylight could easily be obtained.

* A lumen is a unit of light quantity, much as a calorie is a unit of heat. Strictly speaking, however, it is a rate of flow, so that the true parallel is to calories per minute. An ordinary 100-watt bulb is scheduled to give an output of 1270 lumens; the light falling on this page—if you are reading by artificial light—is probably between two and ten lumens per square foot.

How it Began

Street lighting is, of course, essentially a product of the machine-age. Prior to the nineteenth century some districts imposed an obligation on citizens to mount an oil lamp over their door to light the road; but as the modern wick-lamp had not then been invented the general illumination given by these must have been extremely poor. In 1805–08 came the first demonstration of lighting as applied to a whole street, when F. A. Winsor, an enthusiastic publicist of German origin, caused a row of gas lamps to be set up on the wall dividing Carlton House Gardens from The Mall. These lamps of course used no mantles, but owed their luminosity to the bare yellow flame of gas burning at a simple orifice. Gas mantles were not invented till some eighty years later, so the street lighting of 1808 was pretty poor by modern standards. However, the demonstration caused a great sensation at the time, and by comparison with earlier light sources was regarded as brilliant. The new lamps were the talk and the jest of the town, as the cartoon we reproduce indicates; while Sir Walter Scott amused London Society with such phrases as "lighting London with smoke" and "carrying light below the streets in pipes".

While this was going on, Winsor continued to supervise the 'gas-works' in the garden of his house in Pall Mall, and at the same time carried on an unceasing propaganda for his new method of lighting which soon led to the formation of the first gas company. Winsor's own scientific knowledge of the subject seems to have been meagre, if one may judge from his "Plain Questions and Answers Refuting Every Possible Objection against the Beneficial Introduction of Coke and Gas Lights" from which two items are worth quoting:

"Q. Then suppose a room full of gas and you enter it with a candle?

A. It will never inflame because it is intermixed with the air in the room.

Q. But is it not hurtful to respiration?

A. Not in the least! On the contrary, it is more congenial to our lungs than vital air, which proves too strong a medicine. . . ."

Winsor's technical lapses seem to have been compensated by an intense enthusiasm. Every Tuesday and Wednesday evening during the latter part of 1807 his lamps glimmered across St. James's Park, fed from his garden by a $1\frac{1}{2}$-in. pipe of tinned-iron soldered together. The following year the company was formed which we know today as the Gas Light and Coke Company.*

Throughout the nineteenth century gas lighting developed, many ingenious improvements being introduced to increase the light output. At the same time the first electric lamps began to make their appearance, but even up to the end of the century they were still largely experimental, although the implied threat to gas lighting was even then appreciated. The invention of the gas mantle in 1890 by Carl Auer of Vienna increased the light obtainable from a given amount of gas by two or three times, and a still further increase was registered in the first decade of the present century when the cluster of inverted mantles replaced the simple upright burner. Since that time only minor advances have been made in gas lighting, whereas the electric light has made such strides that today it is very favourably placed in relation to cost per unit of light in many districts. This question of cost is of very great importance, for the cost of lighting the streets of Britain is measured in millions of pounds per annum. Every reduction in the cost of light means that more light can be provided, and, as we have seen, it is the small amount of light at present available which is one of the chief difficulties the lighting engineer has to face.

The competition between the two rival illuminants is still very fierce, and actually today many more roads in Britain are lit by gas than by electricity. It is not always realised that many extremely well-lit streets in the centre of big cities are examples of gas lighting. Only last month a new gas installation on London Bridge was formally inaugurated by the Lord Mayor. The existence of this competition from gas light is one of the chief reasons for the low prices charged per unit of electricity for street lighting, so the road user also benefits by it.

To conclude the brief historical survey, then, we have to mention the improvements in efficiency of electric lamps which are probably familiar to most readers of DISCOVERY. At an early stage the carbon filament was replaced by a metal filament which was less easily volatilised and could in consequence be raised to a higher temperature without blackening the glass. Even so, the vacuum tungsten-filament type produced a slow blackening, due to minute particles becoming detached from the filament and flying across the intervening space to deposit themselves on the glass. This effect was much reduced by the introduction of

*These and many other fascinating details are contained in *Lighting by Gas*, by Dean Chandler (pub. S. Met. Gas Co.).

the gas-filled lamp in which an inert gas was introduced which acted as a barrier to these minute particles, and so enabled the temperature to be pushed up further. Finally a method of making the tungsten filament into a tight coil and later a coiled-coil was introduced, which reduced the heat loss by radiation from the filament and again increased the efficiency. It need hardly be mentioned that quite a small rise in temperature represents a very considerable rise in light output; in fact, the light produced is proportional to somewhere between the twelfth and the sixteenth power of the absolute temperature. As the logical upper limit to the production of light by incandescence grew nearer, the gaseous discharge lamp was developed, and the last fifteen years have seen the very widespread adoption of lamps in which light is produced by the passage of electricity through a column of either mercury or sodium vapour. By this means big improvements in efficiency are obtained, but usually at the expense of producing a coloured light which many people dislike. The five-foot 80-watt fluorescent tube which came into use so widely during the war in office and factory is a partial solution to this problem, for its luminous efficiency is more than double that of the filament lamp and the colour is a reasonable approximation to white. The large size of this lamp was for some time considered an obstacle to its use for street lighting, but during the last two years a number of experimental installations have been put up, and it seems likely to establish itself as a unit for very important roads and shopping centres.

FIG. 3.

The Nature of the Problem

The general problem which confronts the lighting engineer whatever the light source is usually this: with a very limited amount of light to make objects clearly visible, without using lamps which are too high or posts which are too close together. Twenty-five years ago the problem was looked upon as a simple essay in illumination, as one might work out the lighting on a billiard-table or a drawing-board. The brightness of such a surface varies as the square of the distance from the lamp and as the cosine of the angle of incidence; and from these two laws one can find out how the brightness of the lamp should vary with the angle of its rays in order that the surface should be evenly illuminated for any given arrangement. The first British standard specification (1927) was based on this principle, but about the same time some misgivings seem to have arisen in the minds of lighting engineers. It was found that if one arranged for the illumination (as measured, of course, on a matt white surface) to be perfectly even over the whole street surface, the result as seen by motorist or by pedestrian was far from uniform. Consider, for instance the brightness of the road caused by the right-hand lamp in Fig. 3. Some 10–15 feet *beyond* the foot of the lamp is a dark patch on the road: but 10–15 feet *on this side* of the lamp the road is at its brightest.

Now if one were to take measurements of the illumination in this street one would find that the lamp is quite symmetrical and the amount of light falling on both these points is just the same. The great difference between them which is observed by the approaching motorist depends, of course, on the gloss or sheen on the surface, and on a wet night the surface will be still more glossy, and the difference in brightness will be even more marked than it is in this photograph. Evidently, then, any attempt to spread illumination evenly over the road—illumination as measured in the conventional way by measuring the brightness of a matt white test-surface—is a waste of time, unless one is dealing with dry new concrete or some such surface. Even dry concrete acquires a polish before long and the vast majority of road surfaces have to be treated as though they were more mirror than matt. A most important feature of street lighting is therefore the bright patch of high brightness formed on the road surface which is really a diffuse image of the lamp in a very imperfect mirror. With this patch as a background, any object is very clearly seen (note the legs of the man in Fig. 3) whereas against the darker parts of the background an object is very much less conspicuous (as is the upper part of the same man) and may even at times be invisible. In this country, therefore, the main emphasis of recent years has been put on the spreading of these bright patches over the road surface in such a way that as even a background as possible is formed. 'Patch-tailoring' is a phrase that has been used to describe this process, which depends largely on a careful layout of the installation. The modern street lighting engineer does not attempt to spread his light evenly as he would if he were lighting a billiard-table; he rather attempts to situate his lamps so that, *when the street is seen in perspective*, the patches of light formed by the diffuse images of the lamps fit together to form a reasonably continuous background. More than that he cannot do, because he

FIG. 4.

FIG. 5.

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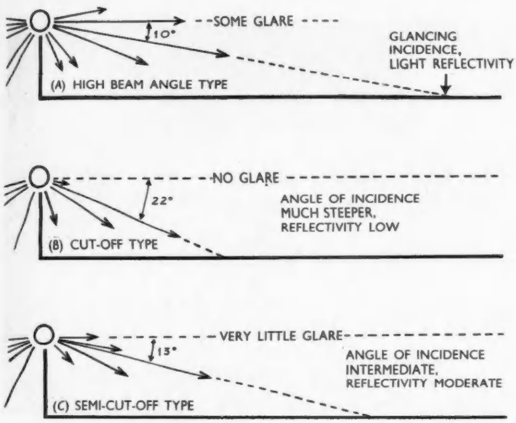


FIG. 6.

knows that the surface of the road will change from day to day as the surface is wet or dry, dirty or clean: and, in addition, the surface is likely to be repaired—possibly altering its optical properties completely—without the lighting engineer being consulted. If one looks again at the photograph in Fig. 3 one can see how the appearance of the road surface has been affected by small irregularities; the manhole-cover near the man's feet, for instance, is very much darker than its surroundings; and the strip of road which has been excavated shows up very clearly in the foreground. If the road authorities were to resurface this road, the whole surface might become as light-absorbing as is the manhole-cover in this picture, and then the road would appear very much less well-lit. Figs. 4 and 5 illustrate this point more clearly; they show the same lighting installation used with different road-surfaces and afford a good example of the effect on visibility of the reflecting properties of the road. Not only does Fig. 4 *appear* less well-lit, but the visibility is in actual fact considerably less good. Almost all our seeing under street lighting conditions depends upon the background and it is rare indeed that the objects a driver wishes to see are brighter than their background unless he uses his headlights. Vision is largely by silhouette of dark against light, whereas exactly the reverse effect is produced by headlamps.

One method of producing a bright background which has been much used is so to design the lamps that the brightest light is emitted at angles of 8°–10° below the horizontal. (A, Fig. 6) It is, as we have just seen, light striking the road surface at these angles which has the greatest reflection factor and so a high-brightness road is produced; also the light patches on the road reach much nearer the observer, and it is therefore easier to make them fill the field of view evenly. Unfortunately this method also increases the glare-effect at the observer's eye, and although some experiments made in London in 1937 indicated that this glare was not enough to detract seriously from visual acuity, there is really no doubt that it is displeasing and tiring to driver and to pedestrian.

The other method of producing good visibility conditions is almost the exact opposite; it is 'cut-off' lighting, in which no light is emitted on the horizontal, and very little at 10° below. An opaque shade or reflector cuts all the light off at these angles, and redirects it downwards, usually with a maximum of about 25° below the horizontal (B, Fig. 6). This method removes glare almost entirely, so the motorist's eye is greatly eased and comforted, but because of the absence of glancing-angle reflection the surface of the road as a whole is much less bright than in the first method. Furthermore, the bright patches on the road are much shorter, so it is necessary to bring them closer together: i.e. the lamps must be more closely spaced. This does not necessarily mean closer columns, because it may be possible to string them in lozenge-shaped formation over the road from span wires going along the axis of the road as well as across it. This method has been used with great effect in Holland and some other continental countries, but has been relatively little used here. Purley Way, the main thoroughfare which runs by Croydon airport, is probably the best-known example here, and this seems to have won very general approval amongst motorists.

There is a third type of lighting intermediate between these two, known as 'semi-cut-off' or 'controlled-cut-off' which occupies a half-way position with some of the advantages and some of the drawbacks of both (C, Fig. 6). With relatively short spacing (but not so short as is necessary with cut-off lighting) very good visibility can be obtained in spite of a rather more patchy appearance, and the system is virtually free from glare.

All three systems have their earnest protagonists, and at one time discussions between supporters of the relative merits of 'high-beam-angle' and 'cut-off' could almost have been mistaken for a debate on socialism versus private enterprise. Of late there has been a marked waning in the popularity of the high-beam-angle type, possibly connected with the increased use of mercury discharge tubes in the horizontal position. Sodium vapour lamps have been used horizontally from the first, but mercury lamps can only be used in this position if a special magnet be used to deflect the discharge away from the glass walls of the lamp. It is very much easier to control the vertical spread of light from a lamp which is in the horizontal position, and it was noticeable at last year's display of street lighting at Southport that nine out of ten electrical installations used discharge tubes of one kind or another mounted horizontally.

The whole question of visibility in streets has more in it, however, than the choice between these three systems. Nor is the visibility of motorists the only criterion, though on main roads probably the most important; pedestrian and cyclist need to find their way about and the police need a lighting system to assist them in combating crime and misdemeanour.

Furthermore, lighting has an amenity value: and J. M. Waldram, one of the outstanding authorities in this country, has recently pointed out* the importance of a high brightness patch immediately under the lamp in promoting a sense of cheerfulness and brightness. Some street lamps which have been developed have certainly erred by redirecting too much of the light into the beam; a certain amount of spillage under each lamp is convenient for pedestrians (who may wish to consult football results in their evening paper) and makes the whole appearance of the road more cheerful.

* *Trans. Illum. Eng. Soc., Lond.* **12** (8), 167 (1947).

FIG. 7.

FIG. 8.

Recent Developments

Street lighting is a subject which invites all sorts of revolutionary proposals from those whose acquaintance with the subject is slight. Why not play searchlights on the clouds? Why not have lights concealed in the kerbs? Why not have lamps on short posts below eye-level? These are three of the suggestions which have often been made, but there are good theoretical reasons for saying that none of them are in the least likely to be successful in practice. Two new developments which are about to be described are of a different category, for it is fairly certain that they would never have been introduced except by persons having a thorough understanding of their subject.

This is particularly the case with one-way lighting, the new idea which has great possibilities for double-track roads. In essence, this may be regarded as a series of motor headlamps mounted on posts and pointing *towards* the overcoming traffic. Seeing the scheme described thus, many readers of this article will shrink back, appalled at the idea. "Towards the traffic" they will say, "surely you're mistaken. Shouldn't it be *with* the traffic? Isn't it frightfully glaring?"

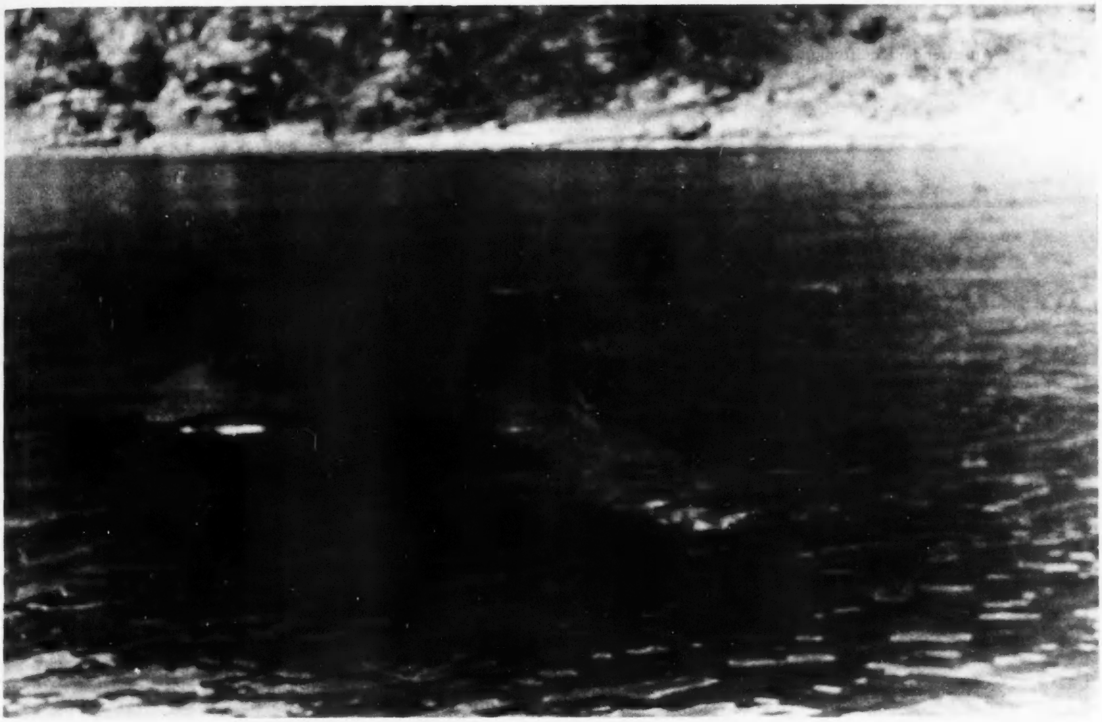
This is a very natural reaction, but one should remember that (1) the lamps are 25 feet above the ground; (2) they are no more glaring than any other street lamp; they may be less so; (3) the brightness produced on the road surface is almost exactly the same as if twice the light were used in an ordinary lantern, and (4) lamps shining *with* the traffic would be less effective (and much more expensive) than headlamps carried on each car; furthermore every vehicle would be continually driving into its own shadow.

Fig. 7 shows an example of this kind of lighting, as installed at Twickenham. This is a double-track road, and it is important to note that when this picture was taken *both* tracks were in lighting. The fact that the other track looks as if all its lamps were extinguished is a tribute to the efficiency of the system; if viewed in the other direction the right-hand track would look bright and the left-hand would look as dark as the right-hand one looks now.

The other recent development is the use of fluorescent tubes for street lighting. This is, essentially a mercury discharge tube in which the ultra-violet radiation has been absorbed by a fluorescent powder coated on the inside of the tube; the absorbed energy is re-emitted by that powder as visible light. By a suitable combination of powders a reasonable simulation of white light can be produced at an efficiency which is more than double that of tungsten filament lamp of the same wattage.

A characteristic feature which for some time seemed to make the lamp unsuitable was its great length and the relatively low electric consumption of even a five-foot tube: however, several manufacturers have recently designed lamps making full use of modern materials by means of which these difficulties have been largely overcome. Two, four or even seven lamps have been assembled in a parallel group enclosed by a Perspex envelope which has the advantage of being much lighter than glass. Reflectors are usually of anodised aluminium sheet, and are so arranged that the lamps present the appearance of a continuous sheet of white light five feet long and one or two feet wide. Even so the lamps are still somewhat cumbersome, and it will take us some time to get accustomed to such large units in our streets. They are also expensive, and lamp replacements are both costly and a little difficult of execution under unfavourable weather or traffic conditions. Nevertheless, the effect produced by this very large area of soft white light is so excellent that we may expect to see a big extension of the system in the future, especially in big shopping streets and at the centres of large towns. A recent installation in Kingsway (London) is shown in Fig. 8.

What will the future hold in store for street lighting? We can hardly expect to see very much large-scale improvement in this country for the next few years as a consequence of the economic position; but it is safe to say that many little-advertised experiments will be going on both in laboratory and street aimed at unravelling more of the mysteries which still invest the subject. The scientific side of the subject is by no means exhausted; and it is fairly safe to suppose that the next significant development in street lighting will be the logical outcome of some such patient investigation.



Basking shark photographed beneath the surface by means of a polarised lens. The dorsal fin just breaks the surface.

The Basking Shark of the Hebrides

JOHN D. HILLABY, F.Z.S.

THE basking shark is a monstrous fish—monstrous in the sense that competent biologists have observed specimens up to 50 feet long, and literally monstrous in the eyes of the popular press where it has conveniently assumed the guise, bulk and mystery of a monster from a medieval bestiary, an apocryphal conjecture in the best traditions of the *acfang*, the *kraken* and the *leviathan* of antiquity.

To assess fully the news value of basking shark in a country where free-swimming marine fauna are not generally remarkable, it is necessary to glance through the files of the more sensational newspapers. At Praa Sands in Cornwall, Stronsay in the Orkneys, Killybegs in Donegal and Arran Island in the Firth of Clyde, monsters were liberally beached throughout the war in varying states of decomposition—floating mines were evidently an adverse biotic factor! The Praa Sands specimen was stated to be over 70 feet long, according to newspaper reports in which imagination was exercised without stint. It was considered reasonably certain in the light of the scanty data available that the fish was a basking shark.

Basking shark (*Cetorhynus maximus*) are not uncommon among the islands of the Hebrides, particularly in the Minch where they share sea room with the small blue shark (*Carcharius glaucus*), the unfriendly thrasher (*Alopecias vulpes*), and the deep-feeding six-gilled shark (*Notidanus griseus*), besides a variety of big and little whales and dolphins. The basking and small blue shark, under the collective name *cearban*, were once hunted by the islanders for their oil, but it was not until 1943 that a young Scot, Gavin Maxwell, began to consider the basking shark as a sporting quarry with an unexploited commercial value.

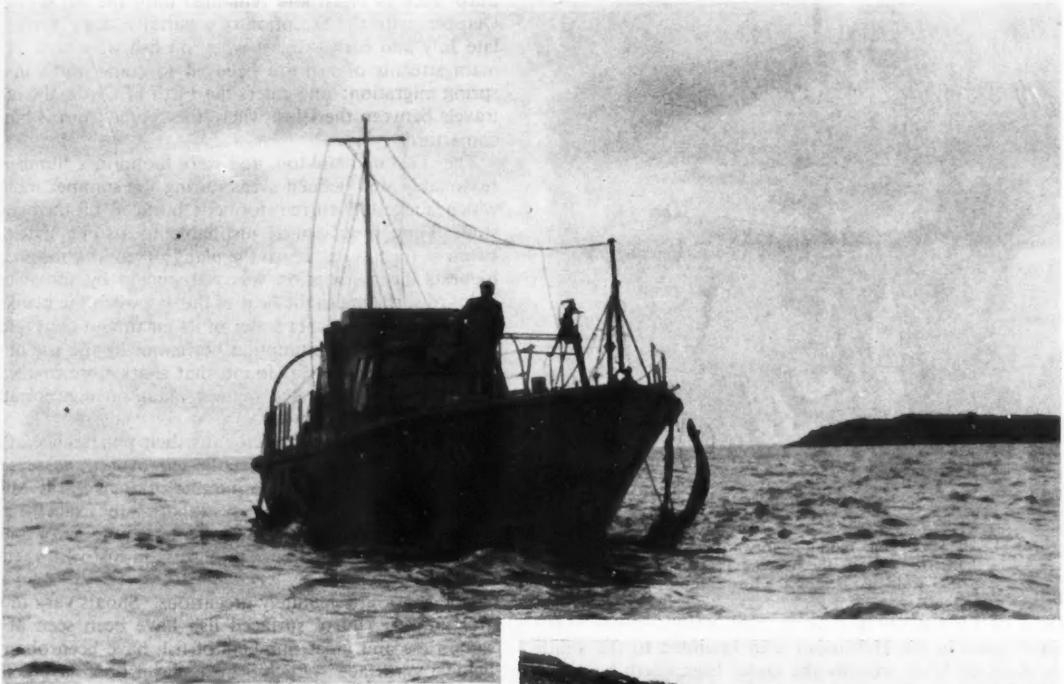
Maxwell had opportunity on his side. His military station was Morar, the deep loch on the western seaboard of Inverness-shire; his duties took him through the Inner Isles where shark were often observed, and he had that inclination towards the unusual which characterises the discoveries of well-endowed amateur biologists. It is to Gavin Maxwell that the present writer is indebted for facts about and the opportunity for observing the shark in their natural habitat.

The basking shark have been reported from Land's End, they have been seen off the coasts of north-western and northern Ireland, round the western Highlands to the

An attendant craft hauls up a shark on a winch.

Handing over to the parent craft.

Secured alongside, the shark is towed back to the factory and hauled up the beach by slipway (*right*).



The parent vessel with a 29-foot shark in tow.

After flensing, the oil is extracted by the steam process, about 1½ tons of oil being obtained from each shark.

The harpoon gun, mounted forward. Approaching the shark from astern, the harpoon is aimed to penetrate just behind the dorsal fin.

Orkneys, and along the Norwegian seaboard. Maxwell hunts them in the Hebridean area bounded to the south by Ross of Mull, west by the Outer Isles, north by a line drawn from the Butt of Lewis to Loch Gairloch in Ross.

The first forays bordered on the homeric. Scanty information came in from lighthouse keepers; the craft used was a 30-foot converted fishing vessel; the steel harpoons were mounted on 12-foot lengths of steel piping and induced at point-blank range by a downward lunge from the foredeck of the craft in the manner of pigstickers; the shark themselves were elusive and uncooperative. One vast fish, sighted within a few miles of the island of Rhum, took the harpoon in its flank, carried off the attendant line and towed the boat round for five hours before it tore free. As the fishers turned back for home they sighted another so big that the possibilities were high on it being the same wounded fish: again they threw their harpoons into its sides. This time it towed them for seven hours into the night. By taking alternative watches in the rising sea and checking their position by cross bearings on two lighthouses, they consoled themselves that the creature must be tiring as it threaded its way through the unknown hazards of the sea bed beneath them. But the end was not anticipated. About one o'clock in the morning they heard curlew where no curlew should be. They were driving towards the mid-sea reef of rocks surmounted by Hyskier Light. They cut free.

But big fish were eventually caught, and Maxwell bought Soay island off the south-west tip of Skye and equipped a factory to deal with the commercial products of the shark—oil, flesh for canning, offal and appendages for fish meal, biochemical products including insulin, and the valuable skin. He fished from a 50-ton motor launch and used a powder-charged harpoon-gun.

Many shark were caught by Maxwell, though they continued to be elusive creatures. They appeared during the third week in April and remained until the beginning of October, with the exception of a curious 'dead' period in late July and early August when no fish were seen. Two main streams of fish are believed to come north in the spring migration: one enters the Firth of Clyde, the other travels between the Isles: where they come from is purely conjectural.

They feed on plankton, and were found in a number of reasonably well-defined areas during the summer months which suggested current-formed 'pockets' of their foodstuff. Though it seemed justifiable to assume that they swam at the level at which the plankton concentration was highest, the assumption was not upheld by the sharks' habit of surfacing in the heat of the day when the plankton should be in the deeper water of its maximum light toleration; nor was the assumption borne out by the use of the plankton net, for it was found that shark were frequently at the surface when the highest plankton concentration was several fathoms down.

Finding no common factor for their appearance at the surface although data was collected over three seasons, Maxwell concentrated on a number of areas in the Minch where he could reasonably expect shark—the exact location of the areas had to be suppressed after a number of opportunists were found to be capitalising on his own observations and industry.

The shark are definitely gregarious. Shoals vary in size and number; thirty surfaced fish have been seen at the same time and great numbers of fish have been observed below the surface in Loch Scavaig, layer upon layer. They had unusual similarity in belly markings and general appearance and were mostly between 25 and 30 feet long.

A 30-foot shark 'played out' and hauled up alongside.

The bone-yard at Soay Island. Although the shark is technically boneless, the pipe-like sections of vertebrae serve to co-ordinate the cartilage.

In the face of an almost total absence of information about the breeding habits of basking shark, Maxwell's own observations are noteworthy: "It is not unusual to see two fish swimming, one immediately behind the other, for long periods at a time. On one day during the second week in May this was particularly noticeable in a number of pairs, and in some cases there were three shark in line. On this day four shark were killed. Of these two had been the leading fish, and both proved to be females. Two others, each of whom had been the following fish of a pair, proved to be males. The snouts of the males were rubbed raw and were bleeding; the intromittent organs were also bleeding. No female fish were seen with blood at the snout, but one female had bleeding abrasions in the anal region. It appears possible that May is the breeding season, and that the eggs or young are produced elsewhere during the winter. No trace of eggs or young have been found in any fish taken to the factory."

The vast size of the fish—they are second only to *Rhinedon* as the biggest in the world—has always been a matter for comment. Thirty-footers are by no means uncommon; bigger fish have been caught, and reliable witnesses have seen fish whose length must have been approximately 50 feet. However, the normal average may be taken as 25 feet and the weight as roughly 5 tons. When feeding (the so-called 'basking' process) they travel at a speed in the region of 3–4 knots and accelerate up to 9–10 knots when questing for or trying to catch up with the rest of the shoal.

Sometimes, when the Minch is apparently deserted by the shoals, they suddenly reveal their presence by a series of prodigious leaps, the full effect of which can be imagined as the five-ton creature leaves the water completely and falls back on its flank. It was thought that the shark were ridding themselves of external parasites in the manner of sea trout or salmon during this performance, but the fact that many sharks jump over a wide area on certain days does not substantiate this theory.

They have two noticeable external parasites: one is a sea louse (a parasitic copepod) which attaches itself in clusters, particularly in the gill regions and frequently attains a length of over four inches; the other is an inordinately large hag fish which have achieved a recorded length of six feet and whose suckers leave scars behind when the hagfishes fall off as they frequently do in the final struggles of the harpooned fish. These scars are quickly exploited by the copepods.

Although shark fishing provides all the attractions of the unusual—particularly among the almost lunar landscapes of the Hebrides—the fish is not in itself aggressive or particularly spectacular, apart from its size. No marine creature, with the possible exception of the orca (*Orca gladiator*) is likely to attack it, and the impressive scars on the flanks of shark caught have been attributed to an unfortunate conjunction with ship's propellers. The shark might be said to be very approachable. Harpoons lodge deep in their body cavities or, pass right through.

When hit, they dive or "sound" at a speed of 15 knots. Some execute a fantastic dance on the surface at the first impact, and all try to rid themselves of the harpoon shaft as soon as possible by scraping themselves on the sea bed, a manœuvre which is often successful.

Maxwell has perfected his own method of fishing which consists of letting the harpooned shark run with no more restriction than the line and some barrel floats (which exhaust them), and then lassoing them when they become more tractable.

They are lashed to his launch, taken back to the factory on Soay island and then subjected to the usual flensing and wet-steam processes.

Nutrition and Symbiosis

E. C. OWEN, M.Sc. Ph.D.

If we leave out of consideration that living crystal—the virus—then, from a structural point of view, the simplest living things are those myriads of species of unicellular plants which we know as bacteria. The bacteria, being devoid of chlorophyll or other photosynthetic pigment, cannot manufacture their own food by trapping the energy of sunshine. Therefore bacteria must find a ready-made source of energy to use as food. This means that bacteria must live on substances elaborated for them by other organisms either while those other organisms are still alive or after they are dead. In the former case the bacteria are called parasites; in the latter case, saprophytes. It would seem then that the net effect of bacteria on life as a whole must be destructive for when they are parasites they cause disease in the other animal or plant in or on which they live. The bacterium which causes typhoid fever, the bacterium which causes tuberculosis and the germ or coccus as it is called which causes pneumonia are examples of parasites. But the destructive activities of bacteria are not confined to their attacks on living things. Many species of bacteria confine their activities to the further destruction of dead organisms. Such destruction is on the average beneficial for it frees the essential minerals locked up in the dead bodies of plants and animals and enables them once more to be absorbed by the roots of green plants and so to become once more available for the building up of new plant and animal protoplasm.

Until recently it was commonly believed by biologists that all the biological work accomplished by the bacteria in their relation to the animals was of this destructive kind. Botanists, however, have for a long time known that the attack of the roots of a green plant by a bacterium or a fungus was not always a sign of disease of the green plant. The reverse was in fact often found to be true; for some plants were known which could not thrive in certain soils unless they were infected with some species of non-green plant either a bacterium or a fungus. Because of the beauty and variety of their blossoms exotic orchids are highly prized plants. Yet provision of an artificial climate in greenhouses was often found not to be sufficient for their cultivation away from their native haunts. This is because an orchid to be healthy needs to have its roots 'infected' with its own specific fungus so as to generate a condition of the roots termed mycorrhiza. Conditions of the soil in the hothouse need, therefore, not only to suit the orchid itself but also to be such that the orchid's beneficent fungus can grow in it as a saprophyte ready to make contact with the newly germinated seeds of the orchid. Orchids' seeds will not grow to maturity in the absence of the fungus. This partnership of orchid and fungus is an example of *symbiosis*, as we call the living together of different species of organisms for their mutual benefit. It is presumed that the orchid plant, being green, provides the infecting fungus with sugars elaborated by photosynthesis. The precise nature of the benefit conferred by the fungus on its host, the orchid, is far from being adequately explained in spite of the arduous labours of many research workers.

The symbiosis of bacteria and higher plants has, however, been more fruitfully investigated and has been shown to be of immense (I choose the word deliberately) economic importance. It is generally believed by anthropologists that the biggest single permanent increase of the earth's human population occurred when man turned from pastoralism to agriculture. Agriculture is a relatively simple pursuit in the annually flooded valleys of such rivers as the Nile, the Indus, the Euphrates and the Si-Kiang, but when fields to be cultivated are away from such flood plains the problem of maintaining the fertility of the soil becomes important. Such soils soon become depleted of compounds of nitrogen. Some time in his development man discovered how to overcome this deficiency by the rotation of crops. In any such rotation, at some stage a leguminous crop, i.e., one of peas, or beans or of clover is introduced and it is found that such a crop restores the fertility of the soil. Botanical research workers, aided by chemists have been more successful in explaining this gain of fertility than they have with the problem of mycorrhiza already mentioned.

Root Nodules

The most cursory examination of the roots of legumes (Figs. 1 and 2) whether cultivated or wild, reveals that they are covered with nodules. These nodules have been found to be due to a bacterial infection of the roots. The presence of the nodules, however, instead of harming the legume, serves to stimulate its growth; for here we have the perfect example of symbiosis. In exchange for carbohydrates photosynthesised by the green leaves of the leguminous host, the bacteria fix atmospheric nitrogen gas, which is continually passing from the air and dissolving in the soil moisture. The nitrogen is fixed in such a form that it eventually finds its way into the protoplasm of the cells of the host plant as protein. Chemists, by making synthetic ammonia, synthetic cyanamide and synthetic nitric acid have learnt how to restore the nitrogen content of soils without using legumes; yet even now man's synthetic efforts are, according to the calculations of A. I. Virtanen of Finland still quantitatively far less important that the nitrogen-fixing propensities of bacteria.

The bacteria which inhabit the nodules of the roots of leguminous plants need a continuous supply of oxygen to enable them to fix nitrogen efficiently. It might at first sight seem that the oxygen evolved during the process of photosynthesis would more than suffice for this purpose. It is, however, not possible for this to occur because photosynthesis occurs in plants only in those parts which possess a pigment such as chlorophyll to catch the necessary energy from sunshine. The subterranean parts of a plant cannot therefore produce oxygen by photosynthesis.

Whence then comes the oxygen needed by the root nodules for fixing atmospheric nitrogen? The answer is: From the air. Both nitrogen which forms roughly four-fifths of the air and the oxygen which forms roughly the remaining fifth diffuse into the pores which occur in the soil, dissolve in the soil moisture and are taken thence by

FIG. 1.—Nodules caused by bacteria on the roots of a wild clover plant. These nodules fix atmospheric nitrogen which ultimately becomes available to the host plant for the elaboration of protein.

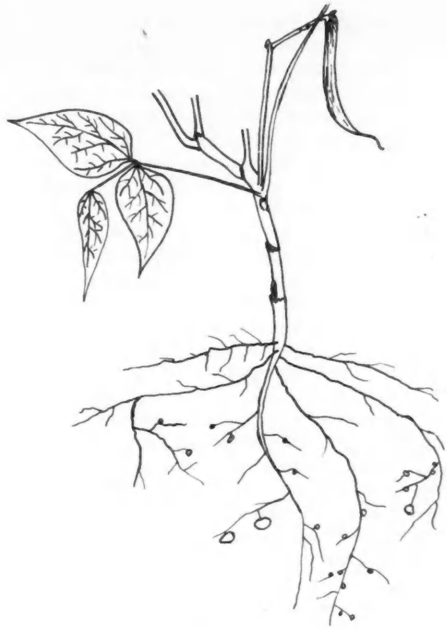


FIG. 2.—Nodules caused by bacteria on the roots of a French bean plant. These nodules perform the same function as those shown in Fig. 1.

the bacteria in the nodules. So the nodules need an efficient means of absorbing oxygen. Now the problem of efficient oxygen absorption arose so early in the course of biological evolution that it was solved by certain worms, one of whose descendants is the common earthworm. It is a matter of simple observation that earthworms have red blood, and it has been demonstrated by biochemists that the red pigment in the worm's blood, as in our own blood, is a kind of haemoglobin. It is a special type of compound of carbon, hydrogen, nitrogen, oxygen and iron, and readily combines with free oxygen. Thanks to haemoglobin a worm may obtain oxygen even though it lives in the soil and a whale can by means of haemoglobin store oxygen to use in its tissues during its long submersions. Until quite recently haemoglobin was unknown outside the animal kingdom. The credit is due to A. I. Virtanen of Finland, recent recipient of the Nobel Prize, for having shown that the bacteria of the nodules of leguminous plants obtain their oxygen by the same biochemical mechanism as that used by all the vertebrates including man himself. There is a red pigment in the nodules and Virtanen has shown that it is a kind of haemoglobin. He has even shown that, as might have been expected from the nature of the environment in which it has to work, the haemoglobin of root nodules has an unusually great affinity for oxygen. This is the first time that the occurrence of haemoglobin has been reported outside the animal kingdom.

Symbiosis means the living together of diverse biological species in intimate association. It is difficult to give a strictly accurate definition of symbiosis because the associations which it implies vary from the simple association of messmates to the intimate association found in *Hydra viridis*, which is a fresh-water coelenterate having as its partner or *symbiont* an intracellular green alga. In its broadest sense symbiosis includes such diverse phenomena as the association, prehistoric in antiquity, of man and dog, and the association found in their nests between ants and other insects. In its narrowest sense it includes such an intimate association as is shown in that plant of dual origin, the lichen, so common on trees in high latitudes and on rocks the world over. For the lichen is not one plant but a consortium of two plants in one. One is an alga possessing chlorophyll, the other is a fungus possessing water-absorbing and water-retaining properties. The idea behind the term symbiosis is the living together of diverse species for their mutual benefit. To be sure that any newly observed association is a case of symbiosis is not easy, for in most cases mere observation is no sure guide as to whether mutual benefit occurs. Many more associations are known to biologists than have ever been proved to be cases of symbiosis. All of us, for example, normally harbour in the large intestine a great variety of species of bacteria. Are they harmful? Are they merely passengers? Is it even perhaps possible that they may be useful to us? It is only as a result of recent experiments that any definite answers to these questions have been obtained. Farm animals commonly harbour in their intestines various species of 'worms'. Here again it is only experiments which have enabled us to know that these worms are harmful and that they are not symbionts but 'parasites'. An animal carrying worms in its alimentary canal can,

therefore, justly be regarded as 'diseased' and to be in need of veterinary treatment. Certain kinds of bacteria and yeasts, however, are present in the paunch, caecum and colon of normal healthy sheep and cattle. These bacteria and yeasts are symbionts because no one has ever been able to show that they cause harm to their hosts.

When one species of organisms lives in or on another as host the following relationships are possible between that species and its host:

(1) The host may be harmed by its associated species, or the latter may be able to cause obvious harm when transferred to another individual of the same species as the host, as for instance when diphtheria germs are transferred from the throat of a 'carrier' to that of a susceptible person. In cases of this sort the host is said to be infected or diseased and the infecting species is called a parasite.

(2) The host may be in better health as a result of its association with the other species. An instance of this phenomenon is the association of beans and peas with the bacteria which cause the formation of nodules on their roots. This is an example of mutual help of the one species by the other so that the bacteria of the nodules must be regarded, not as parasites but as symbionts.

(3) No effect either good or bad of the smaller species on the host may be demonstrable even after exhaustive experiments. Such cases are examples of what is called commensalism and the lesser species is called a commensal. The Giardia, a protozoan found in the human intestine, and the various protozoa found in the paunch of ruminants are regarded by some as commensals.

It will be realised that in symbiosis there is often a balance between one species and the other. For instance *Rhizobium*, the genus of bacteria which cause nodules on the roots of legumes shows a fine adjustment of this balance. On a given host plant some species of *Rhizobium* will cause nodulation of the roots while others will not. Some will cause nodulation but the nodules will fail to fix atmospheric nitrogen. Some actually impair the health of their host. *Rhizobium*, therefore, exhibits all three phenomena of symbiosis, for different species of it may be parasites, simple commensals, or beneficent symbionts on the same species of host plant.

Symbiosis is said to be obligate when, in its natural environment, the host cannot live without its associate. A legume living in soil very poor in combined nitrogen exhibits obligate symbiosis. Orchids likewise in their native haunts are obligate symbionts. Their associated fungus can nevertheless, live as a saprophyte in humus soils even in the absence of the orchid.

Symbiosis is of very general occurrence in both plant and animal realms. Mycorrhiza is found not only in orchids but in many forest trees, flowering plants and ferns. In the humus-rich soils of forests sporophores of fungi which form mycorrhiza on the roots of trees are common. The roots of pine trees almost invariably have mycorrhizas though pine seeds will germinate and grow in the absence of the mycorrhizal fungus. Evidence has been adduced which lends weight to the hypothesis that the establishment of healthy pine forests is in part due to the production of a soil in which the saprophytic growth of the mycorrhizal fungus is encouraged.

A symbiotic relationship between bacteria or fungi and animals is the basis of the commonest method by which

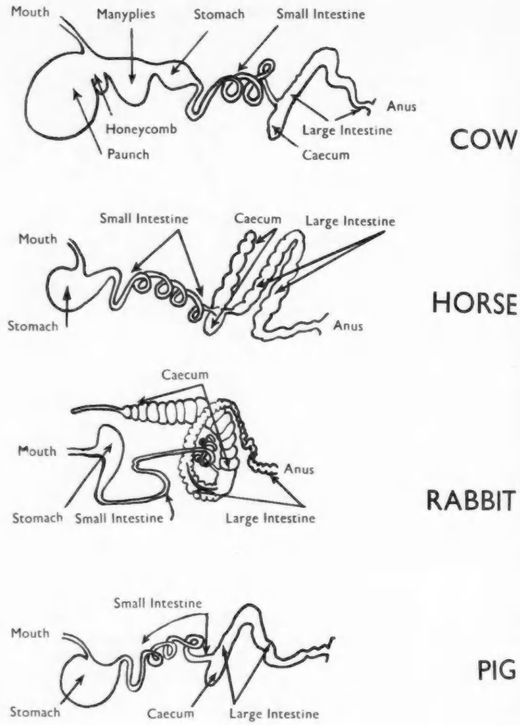
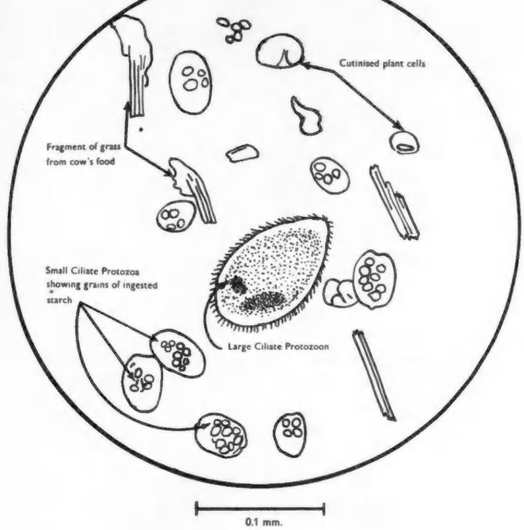


FIG. 3.—Alimentary tracts of mammals of various species, including man. The complexity of the gut of an animal is the greater the more vegetarian its natural diet. The gut of a mammal also tends to be the more capacious the more vegetarian its diet. The paunch of the ruminants and the caecum of animals generally are places in the gut where the passage of food is retarded. In these sites bacteria are abundant and the digestion of cellulose consequently occurs with resulting benefit to the host.

land animals digest cellulose, for the secretion of juices capable of digesting cellulose, as occurs in the ship-worm (*Teredo*) in the slug and the snail and in certain wood-eating insects is uncommon. It is a commonplace of zoologists that the more vegetarian an animal the longer, the more capacious and the more complicated is its gut. (Fig. 3). The frog is a good example. As a tadpole it is a vegetarian and possesses a very long intestine the very numerous coils of which can be seen through the skin of its abdomen. Just before it leaves the water, however, its intestine becomes uncoiled and relatively very much shortened in preparation for its life as a frog. For the frog is carnivorous, eating as it does insects and worms.



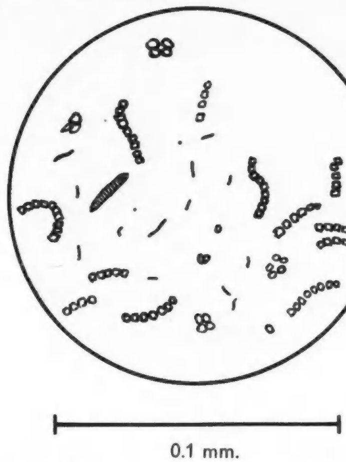


FIG. 4. (*left*).—Protozoa from the paunch of a cow. Such protozoa as the ciliates shown in this drawing from the microscope of material from the paunch of a living animal, are abundant in the paunches of all ruminants both domesticated and wild. They are not parasites, but their effect on the host is still a matter for further research. Hence they are, in the present state of biological knowledge, best regarded as commensals.

FIG. 5 (*above*).—Bacteria from the paunch of the same cow from which came the protozoa shown in Fig. 4. These are symbionts, for they help to digest cellulose and starch and to elaborate protein for the host.

In the mammals the gut shows increasing complication with increasing percentages of vegetable food in its natural diet, and as the complication increases so does the animal's power to digest cellulose. Thus a pig which has a moderate caecum digests cellulose better than man in whom the caecum is very small. The rabbit has a well-developed caecum and can digest cellulose better than the pig. The horse and the elephant have relatively a much more capacious caecum than the rabbit and digest cellulose better still. Microscopic examination shows that bacteria living as symbionts in the caecum and colon are responsible for the digestion of cellulose in all these animals. Pre-eminent in this regard are the ruminants (cattle, sheep, deer and goats) which have a four-chambered stomach, the first three chambers of which are specially designed to facilitate digestion of vegetable food by means of bacteria. In the ruminants, the paunch, which is an enlargement of the gullet, forms a fermentation vat teeming with symbiotic bacteria and protozoa. (Figs. 4 and 5). It is more than fifty years since German biologists suggested that the rumen bacteria conferred benefits on their hosts other than that of digesting cellulose and were, therefore, to be regarded as symbiotic and not parasitic. Only in the last few years, however, have these benefits been in any way rigorously or adequately defined. Most mammals, such as man, cat, dog and pig need to obtain protein in their food. Thanks, however, to its paunch the ruminant can have part of its protein elaborated for it from ammonium compounds. This synthesis of protein is performed by bacteria inhabiting the rumen.

An important effect of the bacteria in the rumen is their power to convert sugar, starch, cellulose and other carbohydrates into organic acids such as acetic, propionic, butyric, and lactic acids, which are absorbed into the blood by the veins which drain the walls of the paunch. Thus much of the carbohydrate of its diet is made available to the ruminant by symbiosis. The ruminant provides in its paunch a suitable habitat for the bacteria and in return has part of its carbohydrate digested for it. Because of this participation of bacteria in the utilisation of its food, the flooding of the ruminant's blood with sugar resulting from the digestion of carbohydrates is not possible. (This may be the reason why diabetes never occurs spontaneously among ruminants but may be experimentally induced in cats by feeding them a diet too rich in carbohydrates. Cats, like humans, have no paunch.)

Symbiosis and Vitamin B-complex

In the more poverty-stricken parts of the world the diseases called beriberi and pellagra occur. These deficiency diseases are due to the absence from the food of certain vitamins of the water-soluble B-complex. The main cause of beri beri which occurs chiefly in South-eastern Asia, where the staple food is rice, is a subnormal intake of vitamin B_1. The main cause of pellagra which occurs in the Balkans, in Egypt, in South Africa and in the Southern States of the U.S.A., where maize is the chief cereal, is the lack of a vitamin called nicotinic acid. In pellagra this vitamin deficiency is aggravated by the fact that maize is also deficient in an essential amino-acid, tryptophane, and that maize contains a toxic substance which interferes with the proper functions of nicotinic acid in the body.

The vitamin B-complex is so called because it consists of some 10 or more different chemical substances, but was,

FIG. 6.—*Amylococcus.* A chain of spherical bacteria (cocci). Their dark colour is due to their storing of starch-like material in their bodies.

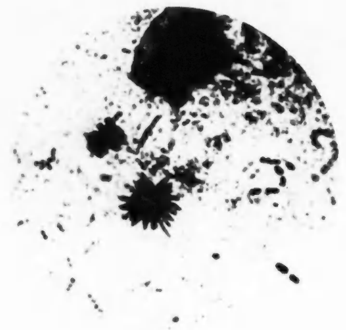


FIG. 7.—*Amylobacter radians.* A star-shaped colony of another species of bacterium also storing 'bacterial starch'.

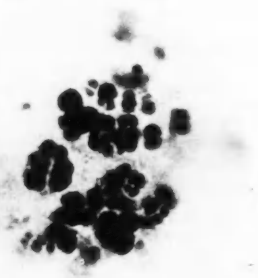


FIG. 8.—*Amylosarcina.* A third species of bacterium characterised by the peculiar packet-like shape of its colonies.

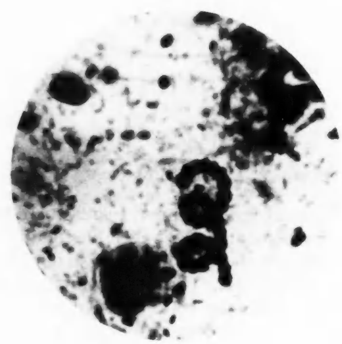


FIG. 9.—*Amylospirillum.* A spiral bacterium.

Notes.—All the species of bacteria illustrated above have the ability to store 'bacterial starch' which like other forms of starch is readily stained an intense blue with iodine. These bacteria absorb soluble substances in the rumen to make this starch, and the bacterial starch so formed becomes available to the host animal when the bacteria are digested in the true stomach and small intestines. These bacteria can also transform carbohydrates in the rumen into simple fatty acids which are also of nutritive value to the host. Because of this latter action these bacteria provide the host with energy from the food in the form of fatty acids as soon as the food is eaten and swallowed. They thus perform a function analogous to that of saliva in man, for saliva turns starch into sugar and sugar is an immediate source of energy for man.

when evidence was first adduced of its existence, thought to be a single substance. The identification of these vitamins of the B-complex and the demonstration of their importance in the metabolism of almost all forms of life, whether green plants, fungi, protozoa or higher animals has greatly increased the known examples of symbiosis. Grass-eating or browsing animals receive their vitamins of the B-complex from their food, for green leaves are portmanteaux packed with all essential animal nutrients. Cows, however, often exist in the winter on diets not containing sufficient of the members of the B-complex. Such animals nevertheless secrete in their milk and urine much more of certain members of the B-complex than can be found in their food. The explanation for this paradox is that symbiotic micro-organisms inhabiting the paunch synthesise the various vitamins of the B-complex for the ruminant.

What is now known to be a mutualistic symbiosis was once the cause of much trouble in early attempts to assay members of the B-complex by using as an index the rate of growth of rats. Certain rats on experimental diets free from the vitamin under test were found to suffer no disability, whereas others succumbed on the same diet. Investigations showed that the ability to withstand such deficiencies was due to the power, developed by some of the rats to synthesise the vitamins they needed, and that the seat of synthesis was the rat's caecum. In the rat's caecum live a variety of species of bacteria and sometimes of yeasts as well, and it is these symbionts which can make for the rat the vitamins which are missing in its diet. Thus rats from which the caecum has been surgically removed can live normally if their diet contains the vitamins of the B-complex. Such rats cannot however live on a diet free from B-vitamins. A less drastic method can also be used to

FIG. 10.—A symbiotic protozoon from the rumen of the ox. Though only a single-celled organism it has a 'cell-mouth' for taking in solid food. A 'cell-stomach' in which solid food is digested and a 'cell-anus' through which undigested residues are passed out.

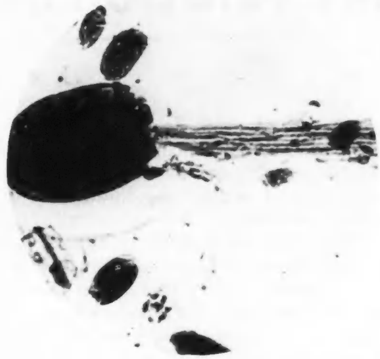


FIG. 11.—Another specimen of protozoon from the rumen of the ox, in the act of trying to swallow a piece of grass bigger than itself. It is probably seeking the bacteria (themselves too small to be seen at this magnification) adherent to the piece of grass.

demonstrate the dependence of the rat on its caecal symbionts. If rats are given in their food a drug which sterilises the contents of the gut then the symbiotic bacteria are prevented from making the B-vitamins for the rat. An ideal drug for such a purpose is one which inhibits the growth of bacteria but is not absorbed through the gut wall into the living body of the animal. Such a substance is the sulpha drug, succinylsulphathiazole. If there are two groups of rats, one group receiving a diet free from the Bi-complex and making its own vitamins, and the other receiving the same diet together with succinylsulphathiazole, the former group will thrive, the latter not. If, however, ailing members of the latter group are allowed to eat the droppings of the rats of the former group they will thrive also. This is because the droppings of the rats of the former group contain vitamins synthesised by their symbionts, while the droppings of the rats of the latter group do not.

The synthetic activities of the intestinal symbionts of rats may be inhibited in even more simple ways. Thus the dextrinising by moist heat of the raw starch in the food or the addition of filter-paper to the diet will both prevent rats from obtaining B-vitamins from their symbiotic bacteria. Since neither of these treatments kills the bacteria, further experiments are needed to explain these effects of cooking and adding filter-paper to the food. It is plain, however, that a rat may die not because it itself is badly fed but because it has failed to feed properly the bacteria living in its own gut. In the rat it has been shown that the fat-soluble vitamin K may be synthesised by symbiotic bacteria in the caecum.

The most complicated organisms evolving from the Arthropod stem are the insects. Like those other complicated products of evolution namely man and the flowering plants, the insects also gain benefits from symbiosis with bacteria and fungi. Some insects have even developed mechanisms whereby the eggs are automatically infected with the specific bacterium or fungus while they are being laid, with the consequence that larvae hatched from sterilised eggs have their development arrested until such time as the investigator deliberately reinfects them with their appropriate symbiotic bacterium or fungus. In the wood-boring wasps a symbiotic fungus which helps the larvae to digest cellulose is carried to the egg at the time of laying. In an Indian bug a symbiotic bacterium has been found which makes carotene (provitamin A) for its host.

White flour is poor in vitamins of the B-complex and, therefore, when stored, it is not so prone to attack by small beetles as are wholemeal or brown flour. There are, nevertheless, a few kinds of beetles which can live on white flour and it has been found that in these beetles symbiotic micro-organisms synthesise the vitamins of the B-complex. These beetles are therefore not dependent on their diet for the B-vitamins.

It is plain from the foregoing examples that the work of such non-green plants as bacteria and fungi is not, as was once commonly supposed, entirely destructive. Their symbiotic activities show them to be able to confer upon their hosts powers of doing things which unaided, those hosts could not achieve. There is, therefore, something of great value to put to the credit side of the biological account of the bacteria and fungi. As a group their work is not one of pure destruction. Viruses, bacteria, fungi and protozoa living between or in the cells of higher animals or plants very often produce diseases in their hosts. Some species, as for instance the virus carried by the King Edward potato or the Giardia protozoan carried in the bowel of certain men and women, appear to do neither harm nor good to their hosts; other species of which the present article has provided numerous examples confer a benefit on their hosts. Have we here an example of evil evolving into good? Are not perhaps all beneficent symbionts merely parasites against which the tables have been turned by the hosts? Is symbiosis perhaps merely the final stage in the biological evolution of what was originally a parasitic disease? To answer such questions we need more than mere facts of observation and the answers which we give are beyond the bounds of purely scientific thought because they must of necessity be coloured by personal prejudices. I therefore leave these questions as unanswered problems of biological philosophy.

The Evolution of the Aeroplane Propeller

J. BLACK, M.Sc., A.F.R.Ae.S.

THE propeller, or airscrew, as a means of propulsion for aircraft is placed by many people in the same category as the paddle-wheel for ships, owing to the rapid acceptance of jet propulsion. It is a mistake, however, to think of the propeller as out-moded, since in its present highly developed state it is a remarkably efficient method for converting a rotary motion into a thrust. This applies especially at speeds ranging from 300 to 450 m.p.h. as the pure jet does not reach its maximum efficiency until the speed exceeds this range, even though the gas-turbine itself is performing very satisfactorily. It appears, therefore, that the best combination for this operating condition is a gas-turbine driving a propeller, and such a system is receiving considerable attention at present for long-range civil aircraft.

The basic principle of the propeller may be seen in the familiar windmill, which in effect is an airscrew in reverse, in that it takes energy out of the wind, whereas the propeller has energy expended on it and produces a wind behind it, the reaction to which provides the forward thrust of the aircraft. Rotation of the windmill is due to the lateral forces which result when a stream of air impinges on a number of flat blades, radiating out from a central boss, round which they are equally spaced, and in which they are set at an oblique angle to the airstream. The important difference between the modern propeller and the windmill is that the propeller blades are no longer flat plates, but in section have the same profile as an aeroplane wing (Fig. 1); the number of blades can range from 2 to 5—the six blades of the contra-rotating propeller is a special case of the three-blader.

Suppose we cut through a propeller blade about three-quarters of its length from the boss, as in Fig. 1(*a*). We would find that the blade section was set at the pitch angle θ_1 to the plane of rotation, but this would not be the angle at which the blade would meet the air, because at the same time as it rotates it is also moving forward with velocity V_1. Its resultant velocity thus lies along W_1, so that actually it is set at an angle of incidence α to the airstream. Now the motion of an aerofoil section through air at this angle produces a force R, which can be resolved into two components: one a forward force T, which is the thrust pulling the aircraft through the air, and one at right angles to it in the plane of rotation, Q. This latter is the force which the engine torque must oppose in order to keep the propeller rotating in the right direction.

If the forward speed of the aircraft is doubled (Fig. 1(*b*)) but the rotational speed is kept constant, i.e. engine revolutions per minute is constant, it will be seen that the blade is moving through the air at a larger angle, so that if we wish to keep the angle of incidence α constant, we have to set the blade at the larger angle θ_2. The terms used are 'fine pitch' for case (*a*), and 'coarse pitch' for case (*b*).

High Speed Limitations

The performance of the blade sections near the tip presents a serious problem, as its speed through the air is

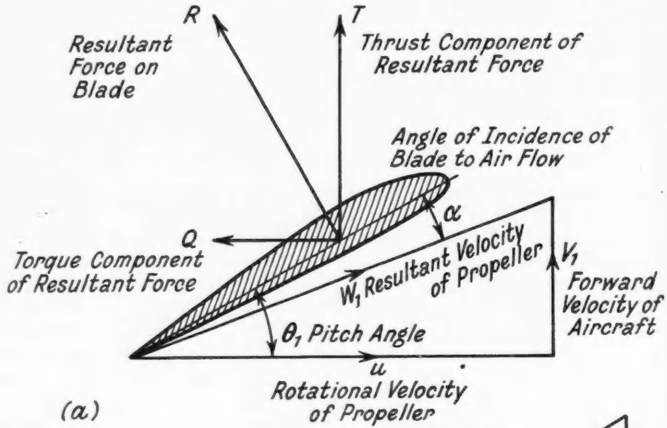


FIG. 1.—Forces produced on a section of a propeller blade when it rotates with velocity u, and moves forward through the air with velocity V. In order to keep the angle at which the section actually meets the air (the angle of incidence α) constant when the forward velocity of the aircraft is increased from V_1 to V_2, it is necessary to increase the pitch angle setting from θ_1 to θ_2. Thus the blade is inclined at a greater angle to its plane of rotation, and its pitch is described as changing from "fine" to "coarse".

very high. For example, the tip of a 10-ft. diameter propeller which is rotating at 1500 revolutions per minute and travelling forward at 450 m.p.h., is moving relative to the air at a speed of 715 m.p.h., and is thus approaching the speed of sound (760 m.p.h. at sea-level). Under these conditions the compressible effects of the air completely upset the smooth flow over the blade, and shock waves are formed. All this disturbance naturally results in a considerable loss of thrust from the propeller, and with normal types of propellers the tip speeds must be kept below the speed of sound.

FIG. 2.—The starboard engine is feathered and the Meteor flies on the 750 h.p. and 1,000 lb. of thrust from the port engine.

The use of thinner aerofoil sections has some alleviating effect on the compressibility, but with thin blades there is a great risk of blade flutter, i.e. the blade vibrates in a complex manner, and if this were allowed to develop it would result in failure, and shedding of the blades. When it is impossible to avoid the shock wave formation, the propeller has reached its limit of usefulness, and the only method of propulsion left is that by jet reaction.

Propeller Development

Fixed Pitch Propellers.—The propellers used until quite recently were all fixed pitch, i.e. the propeller blades and hub were one solid piece. This meant that at only one forward speed were the blades rotating at their optimum condition. Thus, if the propeller were designed for cruising conditions, it would give a comparatively poor take-off thrust, or vice versa. However, if the speed range of the aircraft were not great, a propeller which was reasonably efficient over a wide range could be obtained.

Two-Pitch Propellers.—With the attainment of higher speeds it was found that the performance of the fixed pitch propeller at low speeds was so bad that it was no longer acceptable, and so the 'two-pitch' propeller was developed. This had the propeller blades set into rotatable sockets in the hub which could be operated in flight by a lever in the cockpit. Two settings were available—'fine' for take-off and 'coarse' for cruising, thus the system was analagous to two-gear positions in a car.

Constant Speed Propellers.—It was not long before further increases in speed resulted in a demand for more control over the blade pitch than that provided by the two-pitch mechanism, and the present-day multi-pitch unit was devised. With this, any blade-pitch setting over a considerable range is possible, but no longer is the adjustment of the setting a matter for the pilot. As the engine runs most efficiently at a constant speed, the pitch-changing mechanism is now controlled by a governor on the engine, with the result that any variation of engine speed automatically adjusts the pitch of the propeller blades, and hence brings conditions back to those appropriate to the original constant speed. The pilot therefore only has control over the engine revolutions, and the propeller will then be set either by hydraulic or electrical actuation to its correct setting for optimum performance. A constant speed unit is analogous to an infinitely variable gearbox on a car, which as yet has not been successfully developed.

Feathering Propellers.—The propeller designers, not satisfied with the considerable ingenuity shown in the constant speed unit, provide an even more ingenious device in the feathering blades. In the event of an engine failure, the ordinary propeller becomes a windmill, which means that not only has the aircraft lost the thrust normally provided by the propeller, but in fact has the extra 'windmilling' drag of the dead one added to it. The rotation of the failed engine may also increase the mechanical damage far beyond the original defect.

To overcome these drawbacks the feathering propeller blades can be set at such a pitch angle that there is no resultant force produced on them, hence the propeller remains stationary, and the extra drag involved is considerably reduced (Fig. 2).

Braking Propellers.—The development being carried on at present aims, strangely enough, at a propeller which will provide a negative thrust or braking force on the

FIG. 3—Martin-Baker fighter with contra-rotating propeller.

aircraft. This is called for by the high landing speeds which necessitate a very long landing run. With a braking propeller, the blade setting would be so altered on landing that the aircraft would be brought to a stop more rapidly.

Another advantage claimed is that on large flying boats the ability to have a forward thrust on one side and a backward one on the other would help manœuvring on the water and facilitate docking.

Contra-rotating Propellers

The enormous torque developed by large reciprocating engines, and gas-turbines, cannot be absorbed by even a five-bladed propeller, and as it is impossible to increase the number of blades because of their interference on each other, the solution to the problem has been sought in the contra-rotating propeller.

This consists of propellers mounted one behind the other (Fig. 3), but with each rotating in opposite directions so that, in theory, the complete unit should be capable of absorbing twice the power of the normal propeller corresponding to the front or rear component. Though this is not quite achieved in practice, due to the difficulty of correctly designing the rear airscrew to work in the slipstream of the front one, the advantages of the contra-rotating propeller make it a practical proposition, and it is being widely used.

One of the most important gains is that the air slipstream behind it is straight, whereas behind the conventional propeller it spirals round the aircraft, producing unsymmetrical forces on the control surfaces, etc. In addition, the torque reaction produced by a single propeller is absent with the contra-rotating propeller, since the action of the front screw is balanced out by that of the rear one.

Advances in Construction

The advances mentioned have been concerned with making the propeller more efficient aerodynamically. Equal advances in materials used and methods of construction have also been made.

Wood was naturally the first material used as the contours of the blades were difficult to make in metal, apart altogether from the extra weight. The high centrifugal stresses due to such high-speed rotation lead to the use of laminated wood, in which a homogeneous material is obtained by taking thin laminations of wood and glueing them together under extremely high pressure and heat treatment.

Early attempts at metal propellers were heavy and extremely expensive owing to the complex machining involved. With the introduction of forged blades and new methods of cutting out the profiles, the metal propeller has, however, practically ousted the wooden one for high-performance aircraft.

It thus appears that the day of the propeller is by no means over and that for certain operating conditions it will always be used in preference to jet propulsion.

Centenary of the American Association for the Advancement of Science

ROLAND H. BERG

NEW concepts of the gene—a hint of new atomic weapons—a "colour line" incident which provoked an international complication—a prediction of race suicide from over-population—brain functions explained through mathematical equations—a practical application of solar energy—political persecution of scientists—these were the highlights of a queer mixture of philosophy, politics and science that greeted more than three thousand scientists and guests gathered in Washington to celebrate the 115th meeting and the 100th anniversary of the American Association for the Advancement of Science—"Triple AS" as it is called.

"One world of science" was the theme of the meeting as expressed by Edmund W. Sinnott, director of Yale's Sheffield Scientific School, and president of the AAAS. "Science is universal," he said. "It recognises no national boundaries, is limited by no racial prejudices . . . all these differences, which seem so important in other human activities, are of no significance to science as long as it truly follows its own free spirit."

But this world-wide unity of spirit rang false to Ras H. S. Imru, Ethiopian Minister, who was requested to leave his box where he was seated in Constitution Hall while listening to President Truman delivering the welcoming speech to the AAAS scientists at the opening session on Monday evening. In accordance with his diplomatic rank, Minister Imru had been sent an invitation to observe the proceedings in a box seat. Just as President Truman began his theme, an usher approached the Minister and requested him to change his seat to another, less desirable, section of the auditorium. The Minister left the hall immediately. Who gave the instructions to the usher has never been determined, but profuse official apologies were immediately transmitted to Mr. Imru by officials of the AAAS, and unofficially from the White House.

American Genetics and Lysenko

A near clash occurred with Russian party-line genetics, but was adroitly avoided by Professor Tracey Sonneborn, zoologist of the University of Indiana, and newly elected president of the Genetics Society of America. Professor Sonneborn's paper emphasised that the classic theory of the nuclear gene as the sole determiner of inherited characteristics must be revised. By experiments with *Paramecium* he revealed that environmental differences can react to produce altered inherited character through influence on some substances—plasmogenes—in the cytoplasm. He insisted, however, that his work does not give comfort to Lysenko's pronouncement which holds that environment is the sole criterion of heredity. Sonneborn argued only that the cytoplasm is susceptible to outside influences and can give rise to altered characteristics. But, he insisted, the substances in the cytoplasm are part of the gene system, and his experiments with *Paramecium* do not *in any way* invalidate the gene theory but actually clarifies its operation. By changes in temperature and exposure to certain outside influences such as X-rays, the Indiana zoologist was able to transform normal *Paramecium* into the "killer" species and vice versa, and maintain that characteristic in succeeding generations.

Race Suicide

Instead of hope there were direful predictions of eventual race suicide from many scientists at the meeting. "The cultivable lands of our world," stated Dr. Fairfield Osborne, president of the New York Zoological Society, "are estimated at approximately four billion acres. It is computed that 2½ acres of land . . . are required to provide a minimum adequate diet for each person." (The world's population is estimated at two billion.) He pointed out that population is now increasing at a rate which will double the Earth's present population within seventy years. "Hope for the future of man," Dr. Osborne declared, "rests on whether he realises before it is too late that the maintenance of the Earth's fertility is essential to his survival; further, that there is a limitation to the number of people that the Earth is capable of supporting."

Others joined Dr. Osborne's pessimistic views, particularly Dr. Brock Chisolm, director-general of the World Health Organisation, who predicted that with a population increase of two million persons a month "the world will be hanging out a Standing Room Only sign in two thousand years." Ruefully he admitted that the first project of W.H.O.—malaria control—will increase population problems, although he was quick to point out that ridding an area of malaria will increase that area's food production. But as productivity increases, so will population; and in the end population will outrun productivity.

A Call to Social Scientists

As for mineral resources, the United States is already dependent on neighbours for manganese, tin, chromium, nickel and other essentials, so stated Dr. Thomas S. Lovering of the United States Geological Survey. Man's activities have reached a point, chimed in Professor George E. Hutchinson, Yale University zoologist, "where human assets are the only thing we have in abundance." The tenor of all the remarks called for the joining of hands of natural and social scientists to prevent "freedom from want" from becoming a mere pipe-dream. The call to social scientists was keynoted by President Sinnott who pointed out that while we are bouncing radar beams off the moon, we are at the same time reducing our world to sterility. "We are discovering the secrets of the universe, but we can not," he concluded, "as yet be persuaded to adhere to principles that will ensure the existence of all living things, man included."

One hopeful voice, Dr. J. A. Hall of the United States Forestry Service, raised a possible answer to man's crying need for increased food sources. Wood, said the forestry expert, built the industrial system from which man flourished; and now wood may even be the new source of man's food. In acid processing for the pulping of wood, (the sulphite process, *see* DISCOVERY, October 1948) considerable amounts of sugars are liberated, and are present in the waste liquors that are discharged from the factories. Fermentation of those sugars is possible and is being done in certain countries, while considerable quantities of yeast for human or animal food could be prepared from the same raw material. In North America, two pulp mills now convert the hexose—sugar content of waste liquors—to ethyl alcohol. Operations are commencing for production of yeast from the complete sugar content of the waste liquors. Conversion of the carbohydrate portion of wood to simple sugars is immediately practicable, and Dr. Hall emphasises that approximately half the weight of the raw wood could be converted into the form of simple sugars. By the addition of nitrogen, extracted from the air by known methods, and the addition of small amounts of other nutrients, the conversion of sugars derived from wood to protein could be effected, reported the forestry expert. "We have here the possibility not only of the production of vast quantities of edible carbohydrate material from wood, but also their transformation into nutritive protein, which is perhaps the greatest single dietary lack in most of the world's teeming population," said Dr. Hall.

Alternative Sources of Energy

Lack of food and over-population problems were not the concern of all the scientists. Some, such as Professor Eugene P. Wigner, Princeton University physicist, were wrapped up in the task of developing energy from sources other than coal or oil. Atomic energy is a possibility, according to Professor Wigner, who was one of the key figures in the development of the atomic bomb. In the splitting of the atom, man has for the first time a potential source of power a million times greater than he needs to lift himself and a rocket beyond the Earth's gravitational

pull. A drawback is how to get rid of the excess heat liberated in the process. When atoms of uranium or plutonium are split in the fission process, the speed of the fragments corresponds to a temperature of about six hundred billion degrees centigrade. Overcome this obstacle, and we have a source of energy capable of shooting space ships beyond gravity. Professor Wigner said that the problem of elimination of waste and excessive heat was not too difficult at sea and in the air, and the substitution of atomic power instead of ordinary fuels for such vessels was a possibility in the foreseeable future. A number of current studies, Dr. Wigner asserted, show that nuclear energy is on the verge of competing or replacing conventional fuels. Nuclear energy has approximately three million times as much propulsive force as contained in the same mass of coal; ten million times if we take into consideration the amount of oxygen required to burn the coal.

Along the same line, Professor Farrington Daniels of the University of Wisconsin expressed hope that man might harness the sun and use the radiant energy it pours down on us daily. Even in the temperate zone, he said, solar energy amounted to seven billion kilogram-calories (a kilogram calory equals 1000 calories) per *acre* per *year*, enough "to meet the needs of the human race for food, fuel and power." (*See* DISCOVERY, October, 1948).

Solar House-warming

A woman physicist, Dr. Maria Telkes of the Massachusetts Institute of Technology, has done just that. She announced that as far as she was concerned harnessing solar energy was practical, and that within a few weeks she would move into a house whose sole source of heat would be derived from the sun. At a cost of 20,000 dollars, of which 3,000 dollars was for the solar heating plant, the five-room one-storey home will be completed in Dover, a town fifteen miles from Boston.

The heating unit will be built into the roof of the privately financed structure, consisting of 800 square feet of black metal sheeting behind two glass plates acting as heat traps. Ducts circulate the air behind the metal sheets and when warmed is conducted to 'heat-bins' at strategic points throughout the house. The bins are connected to registers, each serving two rooms. Warm air is blown from the bins through the registers into the rooms.

Storage of heat in the bins is accomplished by utilising a chemical—sodium sulphate dekahydrate—which melts as the heat is stored in it. When the chemical solidifies again, the heat is given off. Heat can be stored for as long as ten days, making possible comfortable warmth even on days when sun rays are not available. The heating system costs nothing to operate, and the chemical lasts indefinitely. When questioned as to what she would do if the solar heating plant broke down during the winter, and if a conventional heating plant would be installed "just in case," Dr. Telkes said emphatically that she would rely solely on her solar furnace and if it broke down she would shiver, "and it will serve me right".

Cybernetics

Without realising it, mathematicians and engineers who in recent years have constructed giant calculating machines, have actually duplicated the human brain. That was the statement of Dr. Hudson Hoagland, physiologist and director of the Worcester Foundation of Experimental Biology, who presented a paper on the rhythmic behaviour of the nervous system, reviewing the published and unpublished work of many physiologists and mathematicians. High-lighted by Dr. Hoagland was the seven-year study of physiologist Arturo Rosenblueth of Mexico City and mathematician Norbert Wiener of the Massachusetts Institute of Technology. They advance the belief that the functions of the nervous system can be expressed in a series of mathematical equations. For this work a new system of mathematics, called *Cybernetics*, has been invented by Professor Wiener. It will be recalled that Dr. Wiener was responsible for the mathematical computations which resulted in the development of many automatic firing devices during the war.

At a special press conference, Drs. Hoagland, Rosenblueth and Wiener attempted to explain the revolutionary concept. At the press conference Dr. Wiener discussed cautiously the ramifications of his concept of the brain as a huge negative feed-back electronic mechanism analogous to a calculating machine, utilising a scanning mechanism of brain-wave frequencies to perform its functions of memory and voluntary actions. Memory, apparently, is not located in a specific brain area, but is diffusely stored as electronic impulses and evoked when the brain receives stimuli of similar frequencies.

A book by Dr. Wiener on Cybernetics (the word is derived from the Greek meaning "steersman of the ship") will be published as a contribution to the understanding of brain function. He claims that this mathematical explanation of nervous system functions will revolutionise psychiatry, and lead to a better understanding and treatment of mental diseases. He pointed out, for instance, that a repression may be an overloading of electrical frequencies, thus jamming circuits and obliterating understanding or stored memory. The scientist gravely admitted that his concepts would not be wholly welcomed by theologians. He also took the occasion to stress that not all he knows has gone into the book on Cybernetics—only that which is safe and presently understandable.

The other scientists at the meeting warily refused to comment lengthily on Dr. Wiener's concepts, except to admit he was brilliant and his theories revolutionary. They preferred to await publication of his book and a thorough perusal. The press felt the same—but even more so.

The Bookshelf

Animals Alive. By Austin H. Clark. (D. Van Nostrand, New York; Macmillan, London; 1948; pp. 433 and index, 22*s*.)

THIS is a difficult book to assess. It is one of a series of books on natural science written for the general reader by members of the staff of the Smithsonian Institution and is, to quote from the publisher's note, "about the world of animals in their relation to themselves, to the super-animal, man, and to the world in general." To cover so vast a field in a single volume is a task that few would care to attempt, and Dr. Clark is to be congratulated both on his courage and on the extent to which he has been successful.

The book is divided into four parts. The first part is entitled "Man and the Animal World" and deals with animals of economic importance. The scope of this section is very wide, ranging from the domestication of the dog to parasitic protozoa, and including two interesting chapters on the variety of animals used as food in different parts of the world. The remaining three parts deal comprehensively with animals from the three main types of habitat—the land, fresh water, and the seas. With the aid of the 38-page index one can obtain information concerning the shape, size, colour, habits, distribution and economic importance of an astonishingly large number of diverse types.

Yet the book is not primarily intended for reference. It professes to be "designed for the entertainment and information of the general reader". Presumably therefore it is intended to be read as one would read a novel. The general reader envisaged is, of course, an American but I would take my hat off to any general reader, American or otherwise, who could read even half of this book at a sitting and retain a significant proportion of what he had read without suffering acutely from mental indigestion. Facts crowd too closely upon one another for cursory reading: one might as easily read an encyclopaedia.

The illustrations are few in number and generally poor in quality, often bearing little relation to the part of the text in which they occur. They do much less than justice to the subject matter.

R. P. HILL

About Cosmic Rays. By John G. Wilson. (Sigma Books, London 1948; p. 144, 8*s*. 6*d*.)

IN 140 small pages, Dr. J. G. Wilson attempts to guide the uninitiated reader through the complex range of phenomena known as Cosmic Rays. He succeeds largely by the use of a concise style and

many drawings which, for the first time in the cosmic ray literature of recent years, show signs of originality. Though, at first sight, not a few readers perhaps will be startled to find on p. 75 an alarm clock flying through the air with the velocity of light! The illustrations showing the growth of a cascade shower in a lead sheet is much more nearly correct than the majority of diagrams that have appeared in books intended for the more advanced reader.

After a brief historical introduction, Dr. Wilson describes the apparatus used in Cosmic Ray research—Geiger counters, cloud chambers, and so on. The main features of the phenomena associated with electron showers are then outlined, and it is shown that they appear to be reasonably well explained by theoretical calculations based on the quantum mechanics of energetic electrons and protons.

Having dealt with the well-established parts of the subject in the first half of the book, the author devotes the remainder to the mesons. These are unstable particles with masses lying between those of the electron and proton. Present-day meson theory is in a pretty unsatisfactory state when it comes to comparing theory with experiment. There are too many theories and too few experimental facts! Dr. Wilson shows that such facts as are well established appear to be in a qualitative sort of agreement with the common features of the theories, but that there is disagreement in many points of detail. The clarification of the experimental properties of the meson group, and the emergence of a generally accepted theoretical viewpoint, is one of the major problems confronting cosmic ray physicists at the present day. This situation will presumably take something like ten years in which to clear up. The general reader is recommended in the meantime to read Dr. Wilson's book for a clear account of the present position.

E. P. George

A Practical Course of Agricultural Chemistry. By Frank Knowles and J. E. Watkin. (Macmillan, London, 2nd edn., 1947; pp. 216, 12*s.* 6*d.*)

Generally speaking, when experienced practical chemists write a text-book on purely practical chemistry, they are on safe ground so far as detailed subject-matter and data are concerned. Whether finally the book is a good one or indifferent depends mainly upon the planning, the choice of material and its sequence, and so on. This is particularly true of specialised technological subjects such as agricultural chemistry. Knowles' and Watkin's book is extraordinarily good from this vital point of view. Their aim has been the senior student of general agriculture or of particular branches like dairying and horticulture. They have sought to include not only the basic methods of agricultural analysis but also quite a good deal of other material that those who specialise are likely to need. Roughly, the book covers B.Sc. degree requirements for either general agriculture or 'departmental' agriculture, and according to his or her needs the student must at various points change the intensity with which the book is digested. If this description suggests rather a confused book, let it be said that nothing is farther from the fact. The book is clear, direct, concise; all indeed that a well-planned book should be. The authors would seem to have revelled in the many difficulties of their task. The original 1937 edition has now been revised where necessary. It is surprising that a second edition or impression was not irresistibly demanded long before 1947.

D. P. Hopkins

Dix ans d'application de la radioactivite artificielle. By Pierre Süe, with a preface by Frédéric Joliot-Curie. (Société d'editions scientifiques. Paris, 1948; pp. 255.)

This is a useful reference book for all those working with radioactive isotopes. Essentially it is an extensive bibliography with a wide and classified range of subjects. It gives a list of radio-isotopes which is less complete than that of Seaborg (*Reviews of Modern Physics*, 1944, Vol. 16, p. 1), which included all isotopes, both stable and unstable.

Men, Machines and History. By S. Lilley. (Cobbett Press, London, 1948; pp. 240, 10*s.* 6*d.*).

This is a competently written and, in many ways, extremely useful work on a broad and fascinating subject—the history of tools and machines in their widest sense in relation to all aspects of human life, from the dawn of agriculture right up to the end of the recent war. The book contains many interesting facts—these are more interesting perhaps than the general style and approach, which here and there are a little workaday and uninspired; for instance, the author tells us that Leonardo da Vinci meticulously recorded all his mechanical ideas, but he omits to add that even Leonardo's roughest sketches were in themselves little works of art.

Dr. Lilley seems to have a remarkable insight into many highly specialised branches of technology. He is at his best—a very good best—in his purely factual passages such as the descriptions of the development of steam power (though he does less than full justice to the high-pressure Cornish Beam Engine), textile machinery and clocks. His account of the principles of Mass Production is also particularly good.

The history of machines cannot be divorced from their social context, and in his straightforward account of social factors Dr. Lilley is also good; as for instance about flying, which he points out is unlike many other inventions in that its success was retarded by *technical* rather than social conditions.

Unfortunately, however, the author has not kept polemics out of it, and increasingly towards the end of the book one is acutely aware of a Marxist bias in argument and choice of quotations.

For example, in his comment, irrelevant in its context, on the Press (p. 92); and his remarks about imperialistic war tendencies (p. 122). This, in the reviewer's opinion, is a great pity as a politically impartial development of the central theme might have carried much more weight and greatly increased the value of an admittedly useful work.

In his preface Dr. Lilley states that this book is primarily aimed at "young people in their last years at school and at universities, technical colleges, continuation schools, etc." whilst keeping in touch with the more knowledgeable type of general reader. In view of my remarks in the foregoing paragraph, this claim wants to be treated with some caution—one is doubtful whether a sixth former, for example, would always be able to discriminate between the author's facts and opinions. By the way, does the author really consider the modern water closet a *minor* invention. To describe it as such strikes one as distinctly underrating its social significance.

Denis Segaller

The Graduate in Industry. By Percy Dunsheath, C.B.E., M.A., D.Sc. (Hutchinson, London, 1948; pp. 276, 10*s.* 6*d.*)

The need for industry to employ more graduates has been stressed in the reports of the Percy, Barlow and Tizard Committees, with emphasis on the importance of using their abilities mainly in the application of existing knowledge. Dr. Dunsheath's book takes the recognition of this need for granted and sets out to provide a guide to the openings for graduates which industry offers. These exist mainly for the engineer and scientist, but the Arts graduate is finding employment in personnel management, administration and market research. In the Engineering faculties, the empirical basis of the subjects has resulted in close links between industry and the universities. Vocational guidance for the graduate is therefore inherent in the courses and is aided by the attention which is given by the professional engineering institutions to practical training within industry. This approach is now being made in the pure sciences.

This book will be valuable to students and teachers in schools and universities by its demonstration of the diversity of industrial functions which are available to the graduate. A useful feature is the inclusion of the requirements of the major professional institutions for their corporate membership.

Dipole Moments. By R. J. W. Le Fèvre. (Methuen, London, 1948; pp. 117, 5*s.*)

This book is one of a series of monographs on physical subjects and is directed to the Honours student and those who are no longer in contact with active scientific work. The latter will need some preliminary revision before starting to read. Methods of determining dipole moments are given in detail and examples of doubtful molecular structure cleared up by reference to the values obtained.

Far and Near

A New Atomic Power Plant

THE U.S. Atomic Energy Commission plans to erect near Schenectady, New York, an experimental atomic power plant to study generation of electric power from nuclear energy. This plant, which will be the first of its kind, will be part of the Knalls Atomic Power Laboratory, operated for the Atomic Energy Commission by the General Electric Company.

A major objective of the design work has been to make sabotage so difficult as to remove it as a threat to continued operation of the reactor.

Unesco Budget for 1949

CRITICISM of the work of the Unesco Administration and its high expenditure have been made by several delegates to the Unesco Conference in Beirut, and in spite of a strong appeal by Dr. Huxley, the Director General, to keep the budget figure at 8¼ million dollars for 1949, the general conference unanimously agreed to reduce the total to 8 million dollars. They asked the budget sub-commission in its review of the detailed expenditure to make every effort to effect economies in order to reduce the total to below 8 million dollars. This resolution was submitted by France and seconded by the United States.

Soviet Academy breaks with Royal Society

READERS of DISCOVERY will not be surprised to learn that the Academy of Sciences in Moscow has broken off its long correspondence with the Royal Society. In announcing this at the Royal Society's annual meeting on November 30, Sir Robert Robinson said that the declaration in *Pravda* that "the Academy of Sciences forgot that the most important principle in science is the party principle" left little scope for ambiguity but was of political rather than scientific importance.

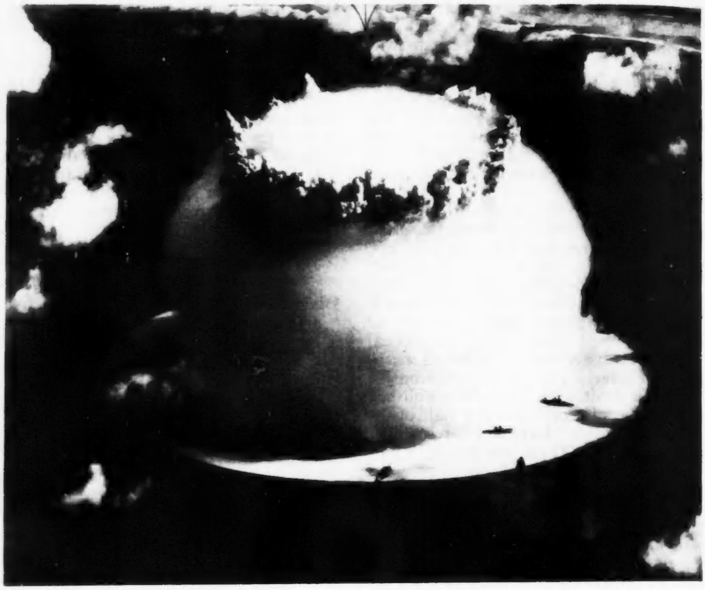
Sir Robert trusted that the new conditions would not impede the advance of biological science, for which such qualifications as 'Western' were as irrelevant as they would be for a multiplication table.

Malaya's Flying Carp

EVERY flying-boat which arrives in Malaya from Hong Kong brings with it 10,000 Chinese carp fry to stock Malaya's freshwater fish farms. Malaya's fish-farming programme aims at giving the population a fish supply more plentiful than most people in the Far East, or anywhere in the tropics, enjoy.

The fry are carried in four-gallon kerosene tins with an average of 500 fish per tin. The space above the water in the tin is filled with oxygen and now more than 90% of these small fry arrive strong and lively. The journey takes only seven hours. Previously the fry came in a five-day journey by sea in huge wooden tanks and losses in transit were very heavy. Thus, it is cheaper to fly the fry, which are sold to specialist fry raisers who rear them on coarse flour and tiny plants grown specially for the purpose. When they reach a length of three to five inches, which they do in a few weeks, they are sold to the fish farmers who raise them to a size suitable for marketing. The mature carp are a valuable source of protein to the working people of Malaya.

The Malayan fisheries department expect the Colony's fish-farming industry—carried out in freshwater ponds in the interior of the country—to reach soon a yearly production level of from 5000 to 7000 pounds per acre of pond.



(Keystone)

The first picture of an under-water atom bomb explosion. This view of the under-water atomic bomb explosion made at Bikini Atoll in the Pacific on July 25, 1946 has recently been released in Washington. Ships used in the experiment are seen in the foreground.

Obituary

THE death of Dr. Samuel E. Sheppard in Rochester, U.S.A. on September 29, has deprived the world of one of the highest authorities on the chemistry of photography.

Born in Kent in 1882, Dr. Sheppard attended St. Dunstan's College, and graduated from University College, London with first-class honours in chemistry. His work in photography which dates from his university days in the early 1900's and has continued until his retirement from Eastman Kodak on January 1 this year, has contributed much to present-day photographic knowledge. An early discovery by Dr. Sheppard and his co-workers, was the effect of sulphur compounds in gelatin on the sensitising action of the gelatin on silver bromide. New means were then devised of standardising such emulsions and producing film of more nearly uniform quality. Another of his achievements was the discovery of several compounds which increased the sensitivity of film in various parts of the spectrum, thus paving the way for the high-speed and panchromatic films of today. Dr. Sheppard's researches extended to other fields as well. His discoveries included a method of using powdered coal as fuel for submarines during the 1914–18 war, and a process for electroplating rubber and rubber compounds which became the basis for an entirely new industry.

Dr. Sheppard has served on several scientific committees, and was a member of many professional and scientific groups, including the Society of Motion Picture Engineers, Optical Society of America and the American Electro-Chemical Society. He was a fellow of the American Association for the Advancement of Science and the Chemical Society, London.

Indian Scientific Liaison Office

THE Council of Scientific and Industrial Research, India, has established an Indian Scientific Liaison Office in London. This office is located, along with the Scientific Liaison Offices of the other Dominions in the B.C.S.O. Organisation, on the third floor of Africa House in Kingsway. Dr. S. Bhagavantam, who was Professor of physics in the Andhra University, Waltair (India), arrived in September of this year as the Chief Scientific Liaison Officer for India, and has been functioning as such since then.

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